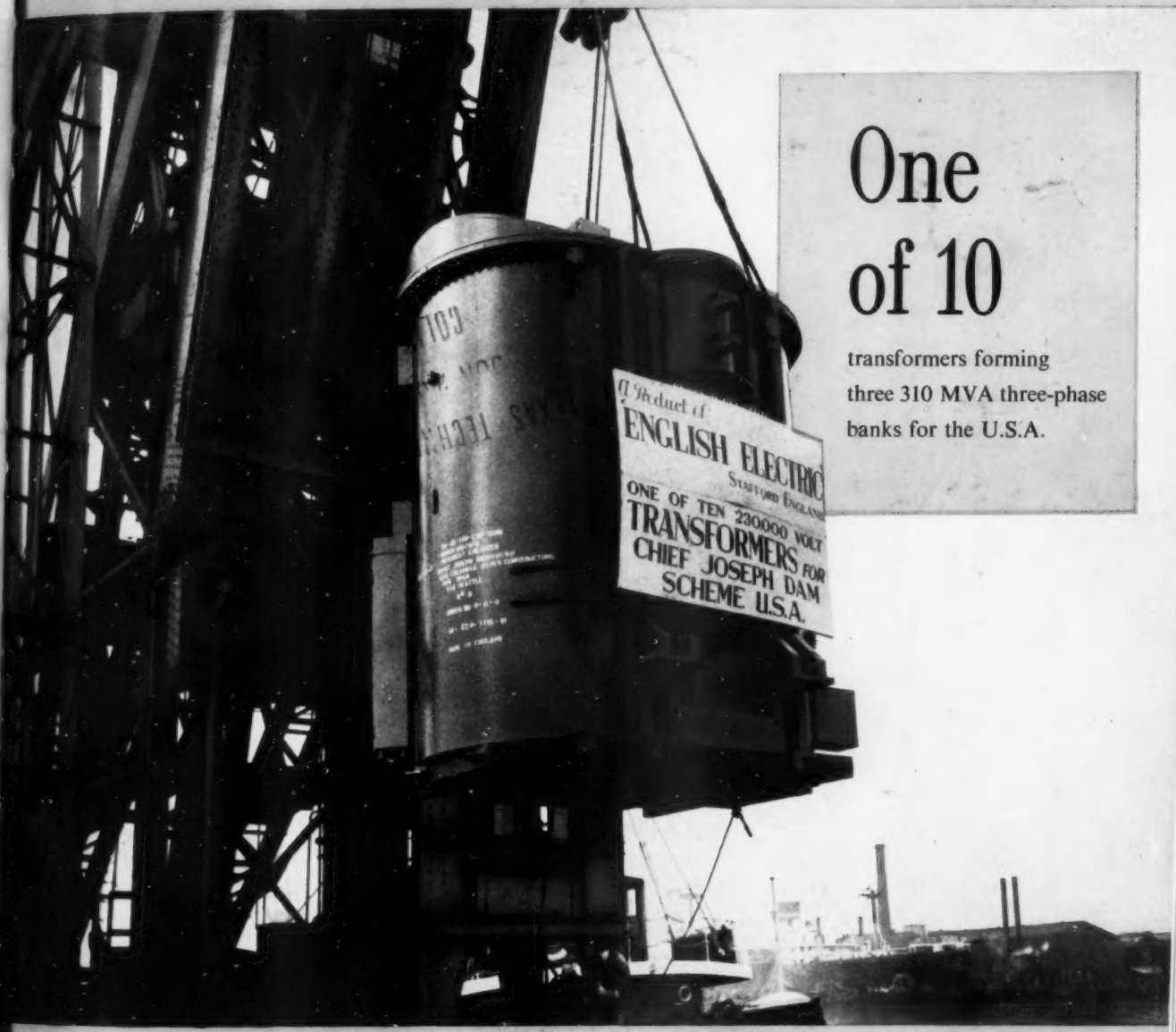
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JUNE 1956



One of 10

transformers forming three 310 MVA three-phase banks for the U.S.A.

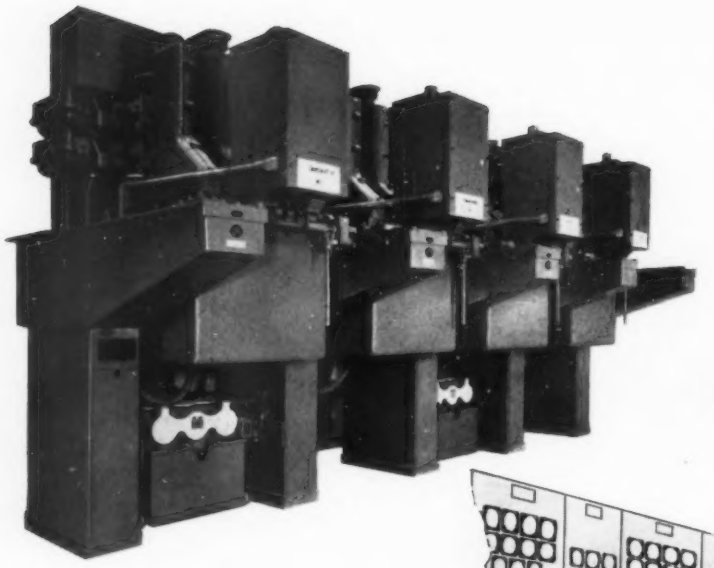
'ENGLISH ELECTRIC'

transformers

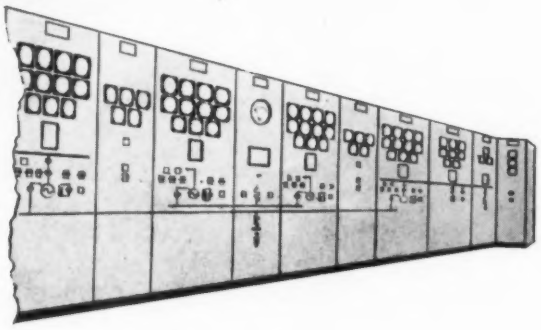
THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Transformer Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON



generator switchgear at Calder Hall



The generators at the
Calder Hall Power-station
of the Atomic Energy Authority
will be controlled by Reyrolle
11-kV 500-MVA and
750-MVA switchboards
and their associated
control-boards

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WEIGHT DRY:	47 lb. (21 kg.)
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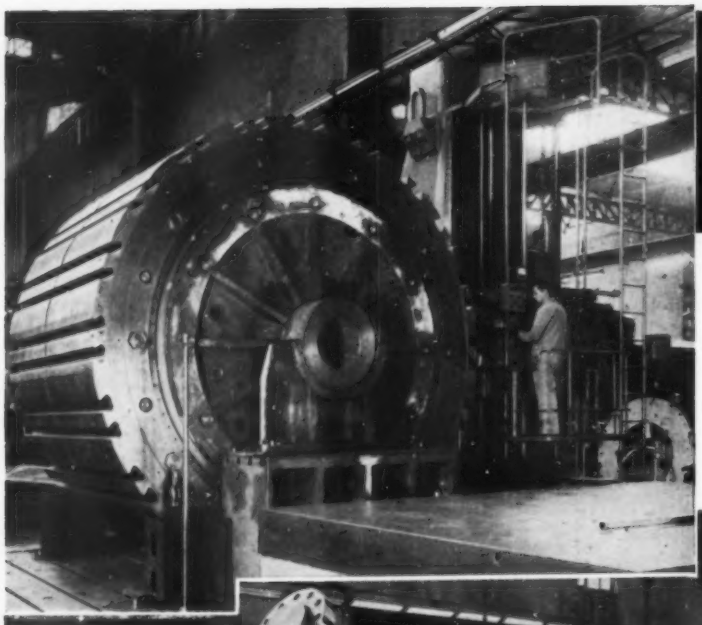

Marelli

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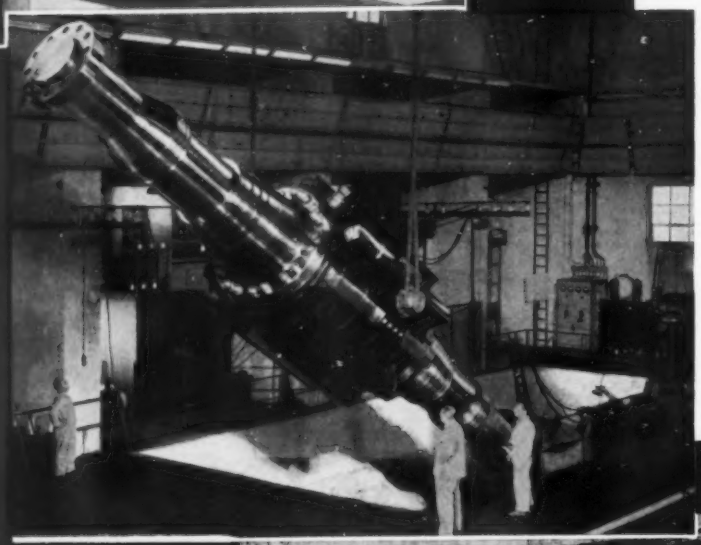
HYDRO-ELECTRIC EQUIPMENT



Rotor, shaft and stator for one of the two Water Wheel Alternators (110,000 kVA—13,800 Volts—300 r.p.m.—weight 650 tons) installed by Marelli in the Cimego Hydro-Electric Power Station of the Società Elettrica Bresciana (Italy). These alternators are believed to be the largest horizontal units yet built.

manufacturers of water turbines of all types, governing equipment and inlet valves up to the largest size for use in all parts of the world
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The largest Overseas Transformer Contract ever received in the United Kingdom

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THIS TIME FOR THE DALLES DAM U.S.A.

Ferranti Ltd. have received the largest overseas transformer contract ever to be placed in the United Kingdom.

The contract covers eighteen 63,000 kVA, 230 kV, single phase and three 63,000 kVA, 115 kV, single phase transformers for the U.S. Army Corps of Engineers Dalles Dam Project, Columbia River, on the borders of Washington and Oregon and is valued at $2,080,940 (£746,000).

It is the fifth contract awarded to Ferranti Ltd. by the U.S.A. in recent years and brings the total number of transformers supplied or under construction to 38 units of a total capacity of 1,972,000 kVA, and a value of $3,827,000 (£1,366,785).

FERRANTI

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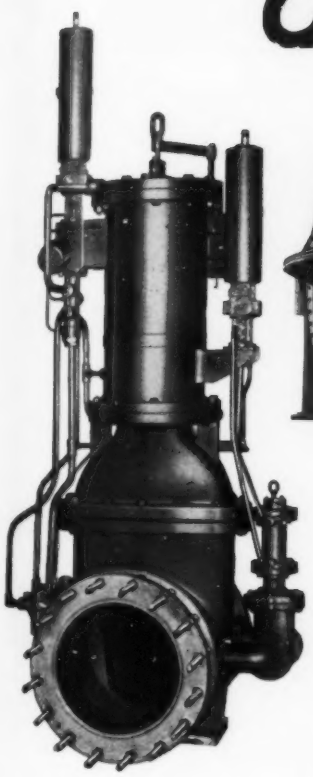
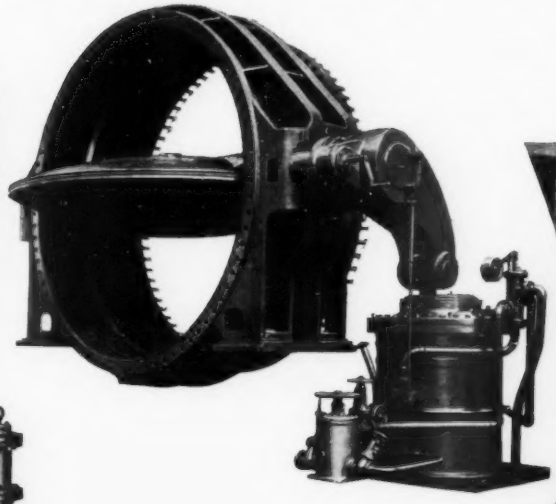
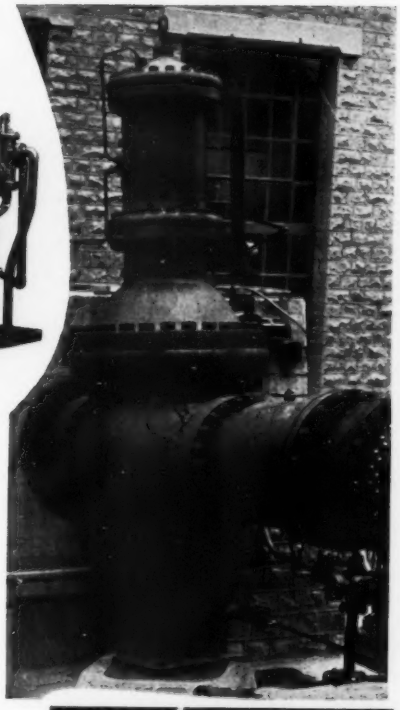
Glenfield Control...

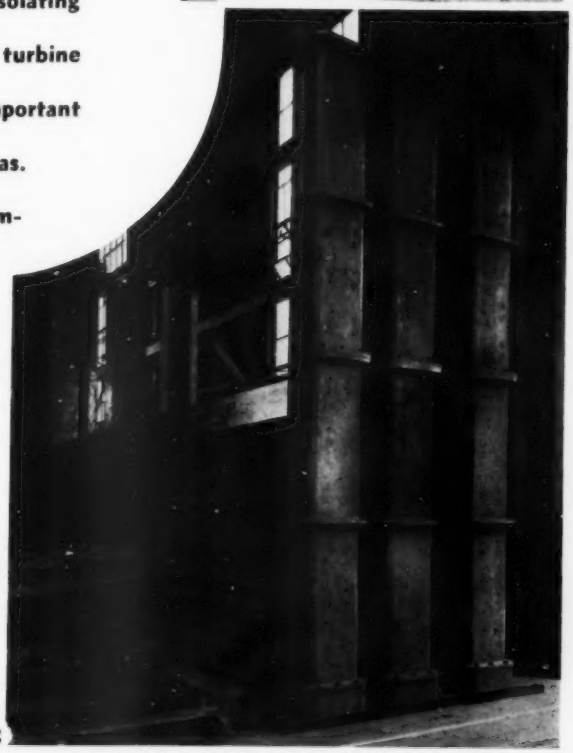






at the Power House

Glenfield Sluice Gates and Valves—butterfly, rotary and sluice—for turbine inlet control or isolating purposes; and Sluice Gates for sectioning-off turbine draft tubes, have been supplied for many important Hydro-electric schemes in Britain and Overseas. They are performing their duties with the complete reliability and efficiency that stems from long experience in the design and manufacture of such equipment.



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2,000,000 KILOWATTS!

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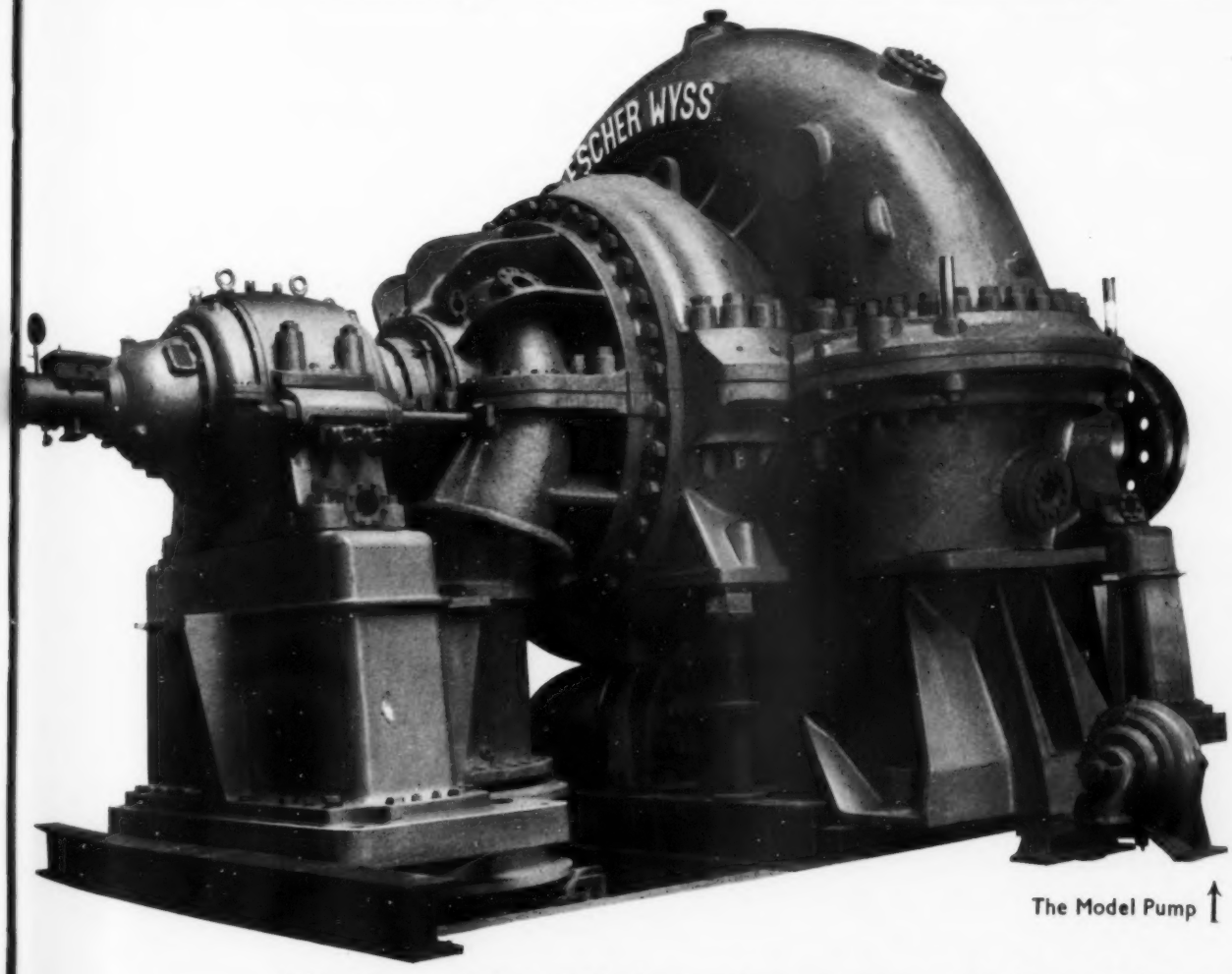
Delivery head	320-420 metres
Discharge quantity of each unit	16.6-10.8 cub. m./sec.
Speed	500 r.p.m.
Maximum input of each unit	**83,800 H.P.**



The Model Pump ↑

Escher Wyss are further participating to an important extent in the delivery of the hydraulic equipment for the Ybbs-Persenbeug Power Station/Austria.

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20 million H.P. delivered by some 16,000 Voith Turbines

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Capacity of pumps 37,500 H.P. each

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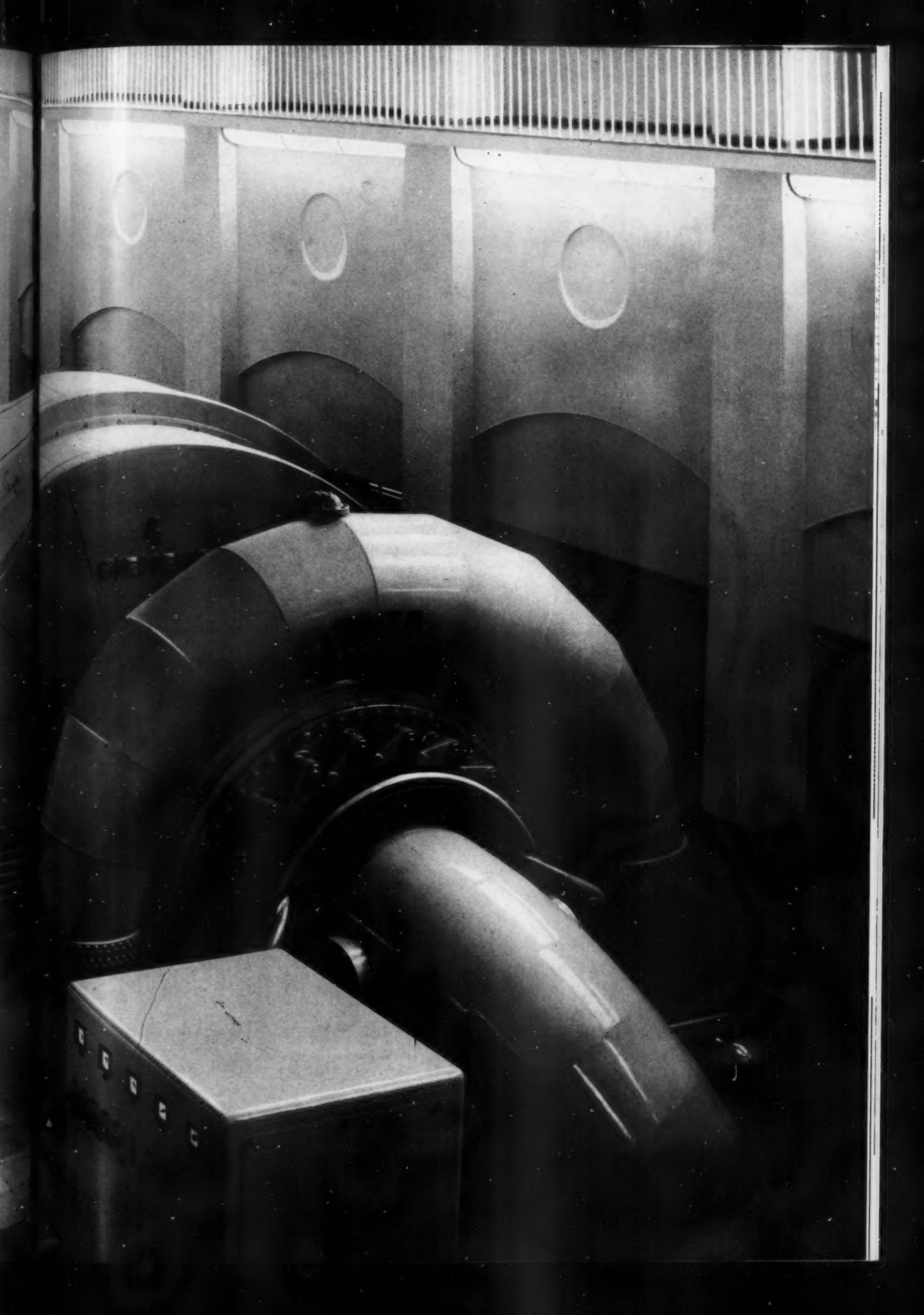
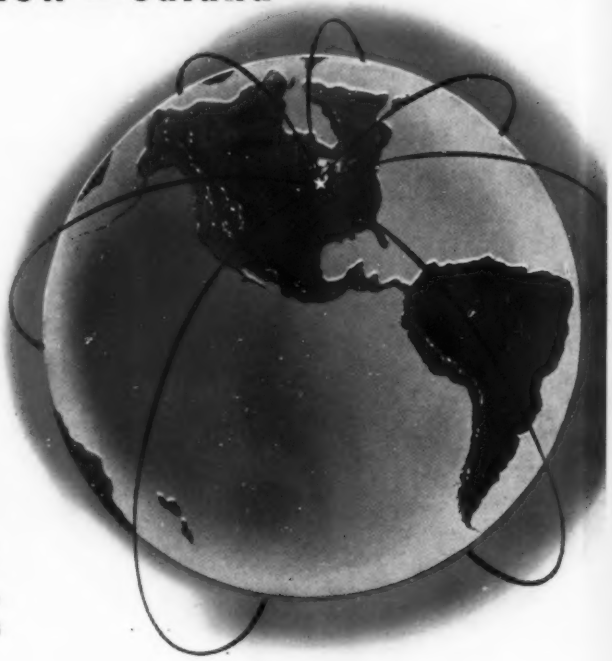


From Alaska To New Zealand

ALLIS-CHALMERS
Hydraulic TURBINES



All Over the World

From Petersburg, Alaska to Maraetai, New Zealand, Over 15 Million Hp is Harnessed by Allis-Chalmers Turbines

Allis-Chalmers builds all three principal types of hydraulic turbines — Francis, propeller and impulse. Allis-Chalmers can also supply nearly all the necessary electrical equipment and auxiliaries, including transformers, generators, switchgear, regulators, valves and governors for large units.

You can often make substantial savings by calling in Allis-Chalmers qualified engineers to help you and your consultants select equipment most suitable for your specific needs. Early consultation gives you the advantages of Allis-Chalmers half-century of experience in designing and building hydraulic equipment.

For all or any part of your needs, call the Allis-Chalmers representative near you or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin, U. S. A. Manufacturing plants in United States and Canada.

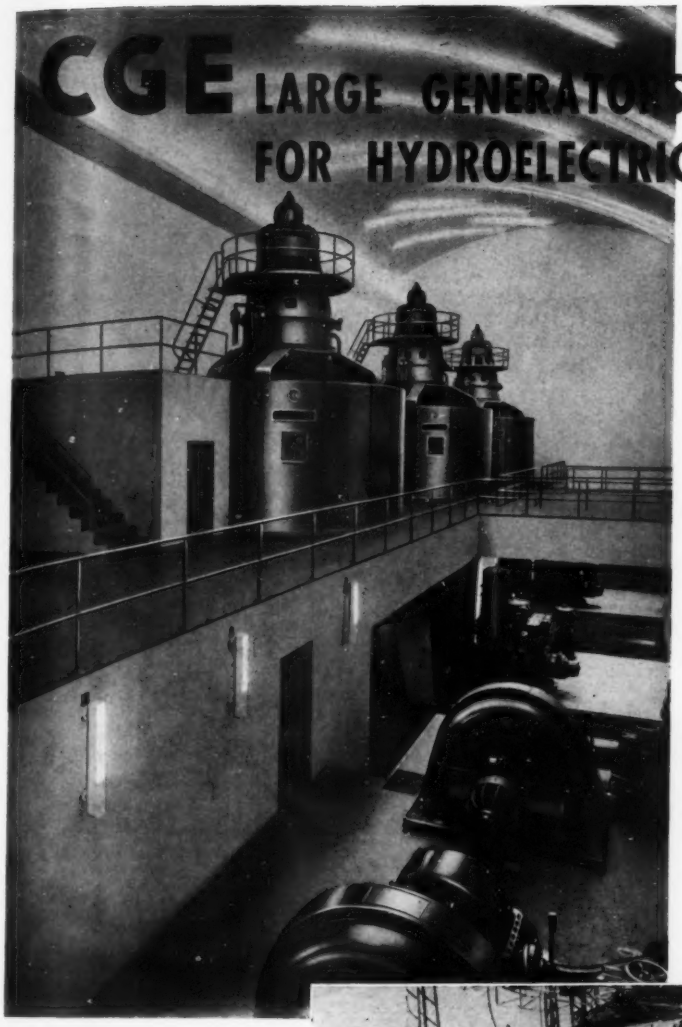
Propeller Type
Normally used for low heads — up to 100 feet — but in exceptional cases higher. High speed unit offers substantial savings in generator costs.

Francis Type
Used for high heads, up to 1000 feet and sometimes even higher, depending on capacity of the unit, quality of the water and characteristics of the load to be carried.

Impulse Type
For heads as high as pressure pipe lines can be built. Used for heads as low as 200 feet if water conditions make use of Francis type undesirable because excessive wear would result.

ALLIS-CHALMERS

A-5040



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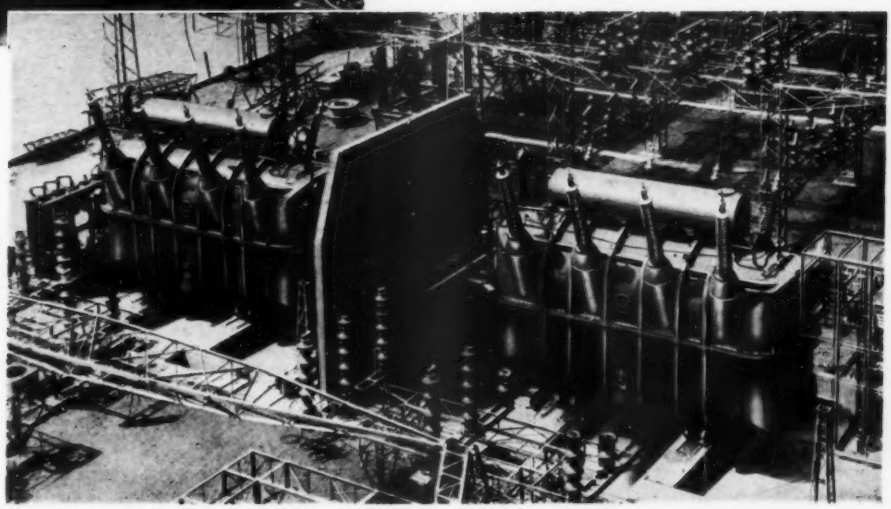
Two 600 KVA auxiliary generators

Two 70/70/70 MVA, 240/150/11 KV, three-phase, three-winding, forced-oil-water cooled transformers.



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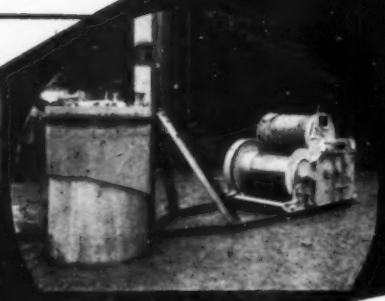

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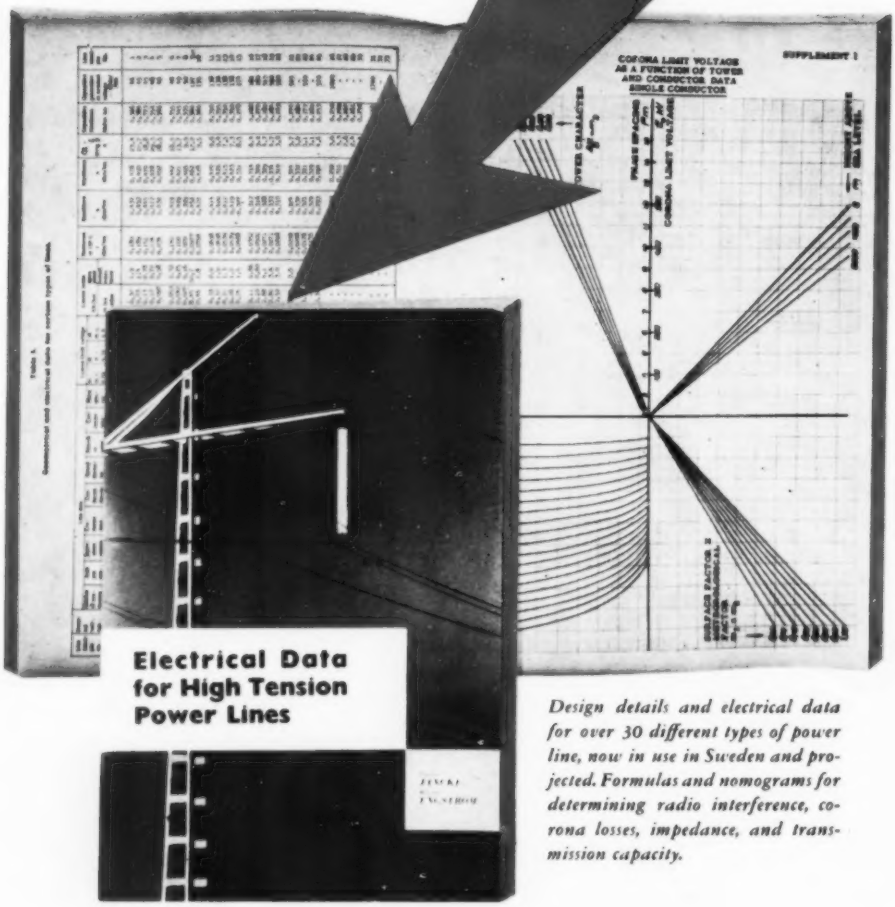

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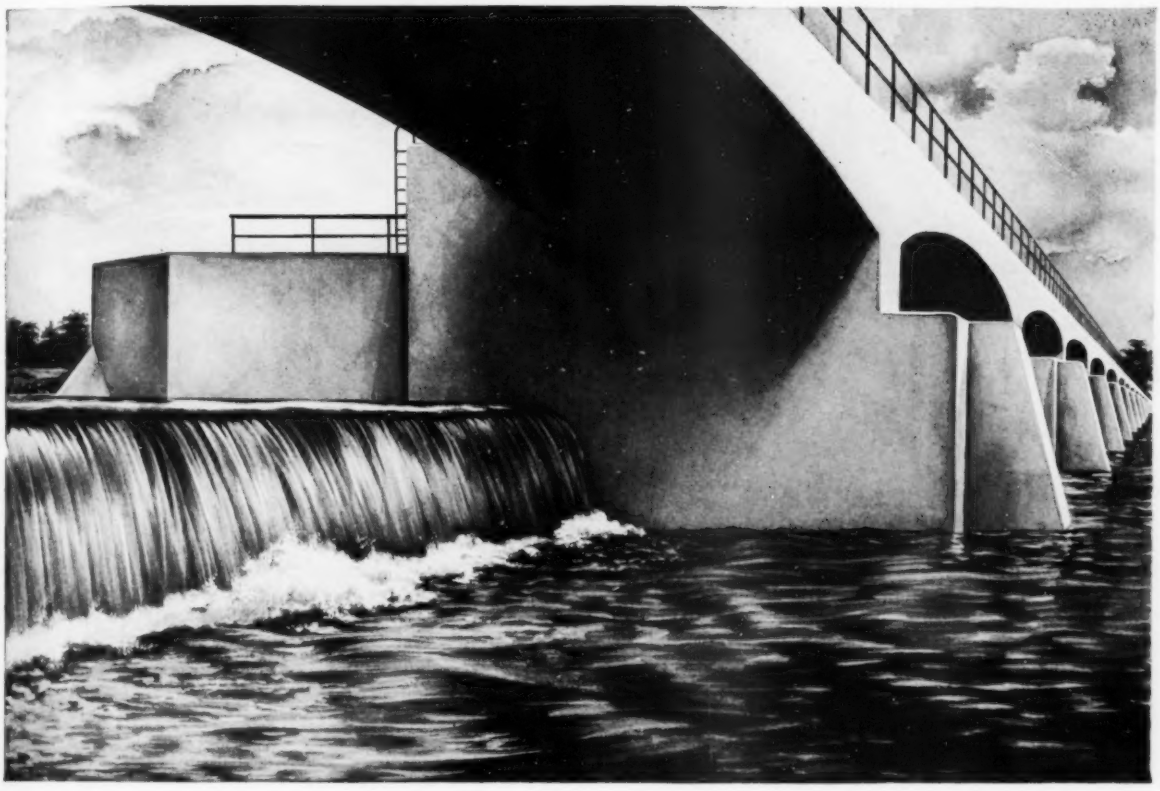

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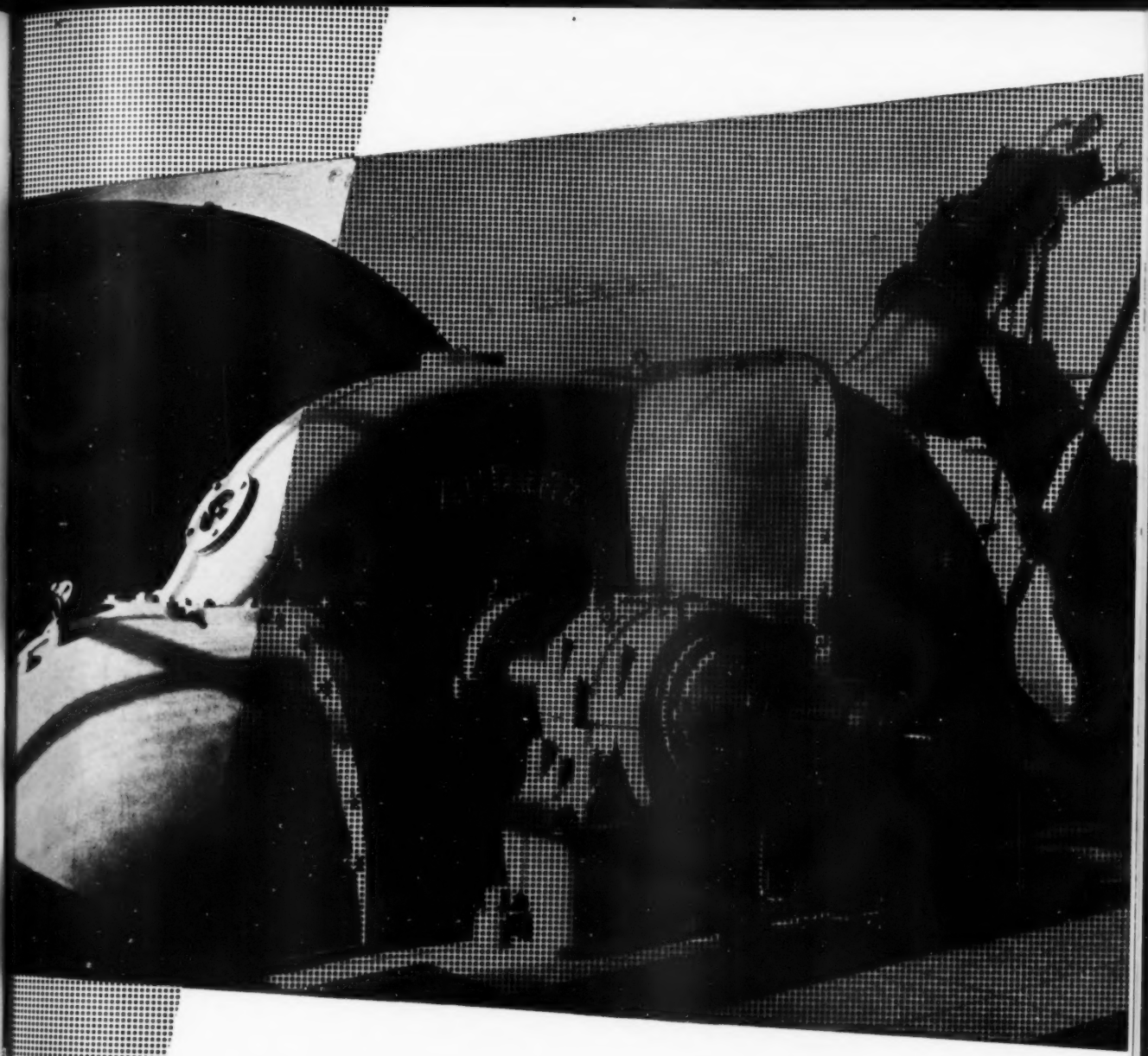

Water Turbines

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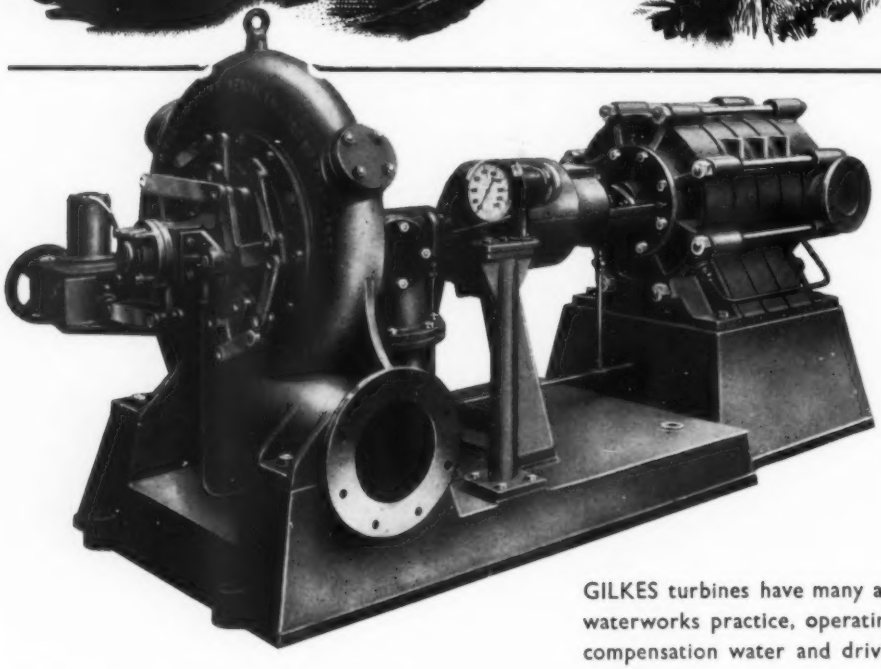
ANDRITZ
ACTIENGESELLSCHAFT
Graz-Andritz, Austria



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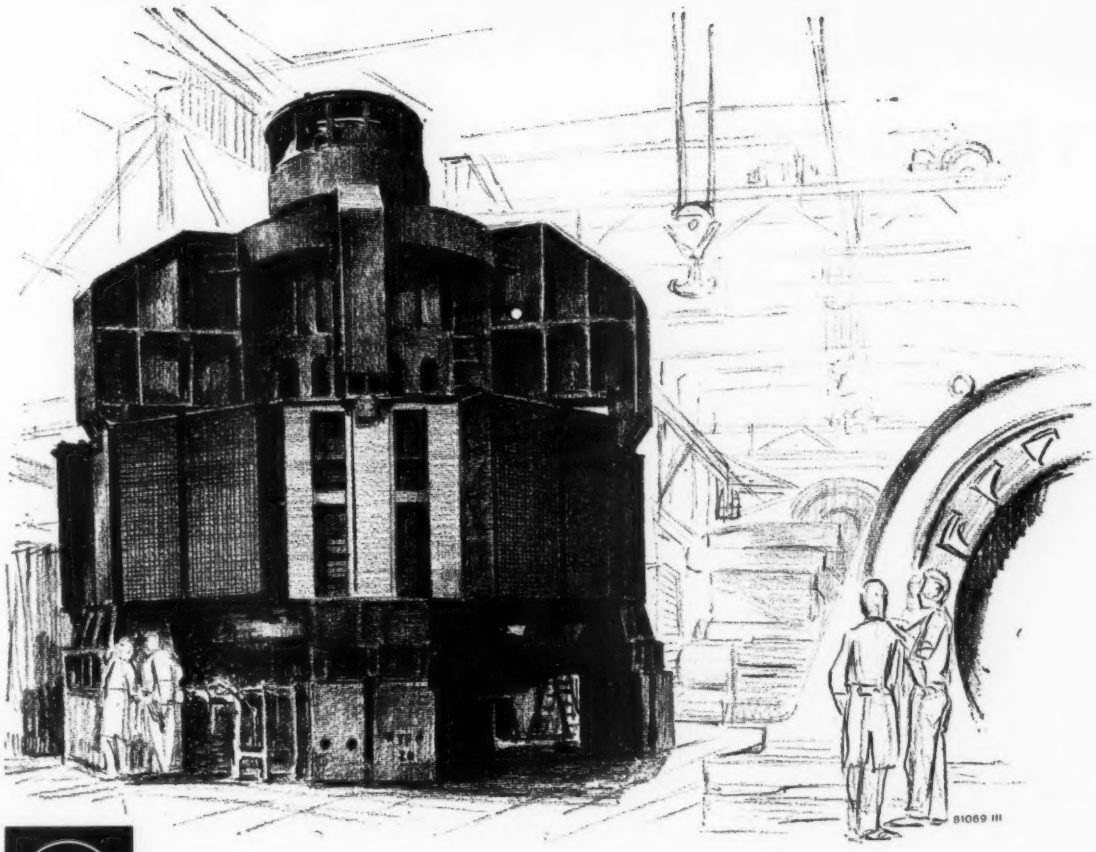

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In countries all over the world . .

and in some cases under extremely arduous working conditions Brown Boveri machines and apparatus are operating to the entire and long-standing satisfaction of their owners.

The charcoal drawing reproduced above is an artist's impression of one of the three 49,500-kVA generators for the Aswan power station on the Nile in Egypt, during assembly in one of the large workshops at Baden. Numerous problems had to be solved in the manufacture of these machines which, with their weight of 725 tons, are some of the largest to be built by us to date. The fact that we are able to supply such mammoth equipment proves that we have the facilities to build the very largest machines.

The same care and accuracy with which these machines were built also go into our other products, such as complete steam, gas and hydro-electric power stations; protecting and regulating equipment for power stations and systems; equipment for industrial applications of all kinds; electric traction equipment; broadcasting and radio-telegraphy transmitters; transmitting and rectifier tubes.

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Emergency Gates
Turbine emergency Gates
Crane Bridges
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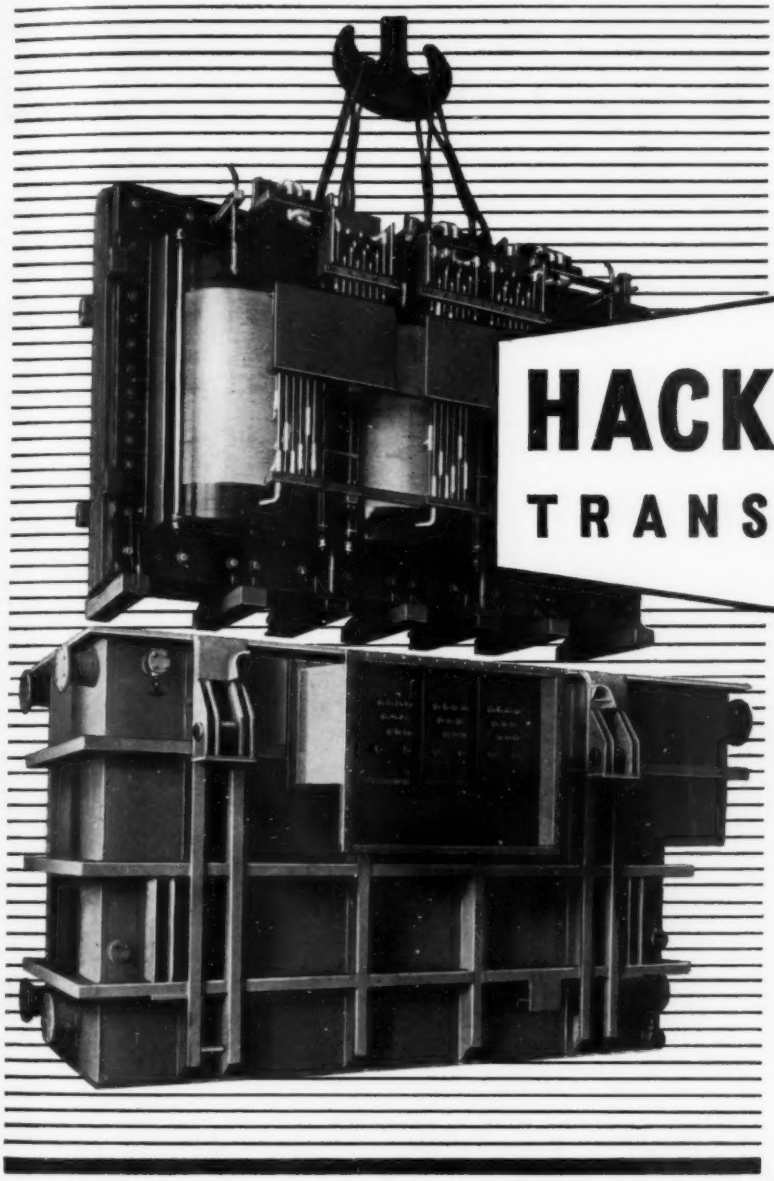

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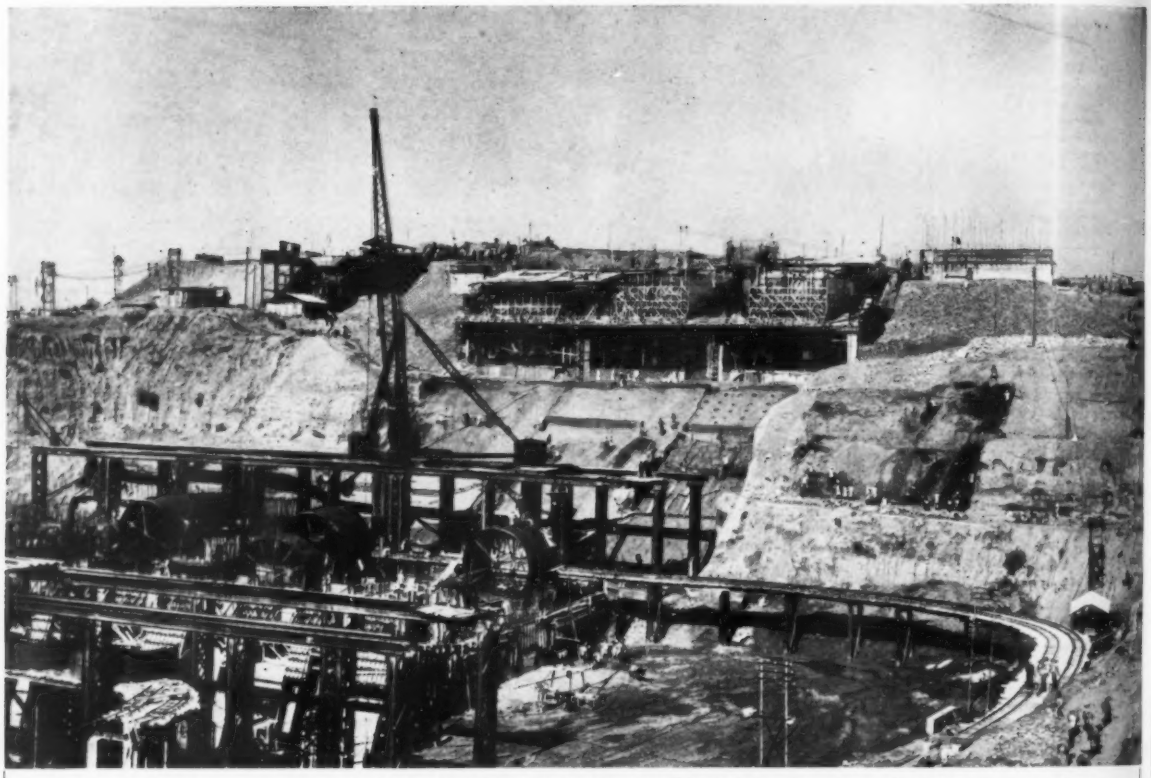
ATLAS COPCO EQUIPMENT IN ACTION ON INDIA'S MIGHTY BHAKRA-NANGAL PROJECT



A power house under construction on the Bhakra-Nangal project. A wide range of Atlas Copco equipment and Sandvik Coromant steels have been used on many excavating and tunnelling operations on the project.

The turbulent River Sutlej is being harnessed under India's £113,000,000 Bhakra-Nangal project. It has three major aims. To prevent flood disasters, to irrigate six million acres of land, and to provide enough electricity for over 100 towns.

The Bhakra-Nangal project naturally means an immense construction programme. It includes the huge, 680-foot-high Bhakra Dam on the Sutlej. This is one of the highest ever planned in the world and the most important feature of the project. The dam will form a reservoir behind it with a capacity of 7.4 million acre feet of water, and the power houses at Bhakra will have an installed generating capacity of 1 million kilowatts.

57 MILLION CU. YARDS OF ROCK

Atlas Copco rock drills, Sandvik Coromant steels and a wide range of other Atlas Copco compressed air equipment have been extensively used in excavation operations to construct the Bhakra Dam. These include excavations for the site of the dam, 575 feet wide at the base, for two cavernous diversion tunnels, each about 2,500 feet long, with the impressive diameter of 50 feet, and for four penstock tunnels. All told, this entailed the excavation of 57 million cubic yards of rock.

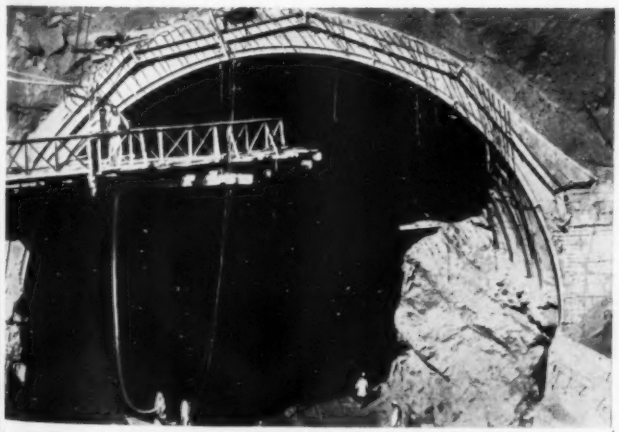
On other excavating operations for the Bhakra-Nangal project, Atlas Copco drills and Sandvik Coromant drill steels have again been chosen, along with Atlas Copco compressors, sump pumps, rock breakers, drill steel grinders and riveting tools.

Among equipment excavating for the foundations of the 680-foot-high Bhakra Dam are Atlas Copco rock drills fitted with Sandvik Coromant tungsten-carbide-tipped steels.

ATLAS COPCO DRILLS AND SANDVIK COROMANT STEELS ARE IN ACTION ALL OVER THE WORLD

Atlas Copco compressed air equipment is being used again and again on many more important projects throughout India. Since Atlas Copco light rock drills and Sandvik Coromant steels were introduced there five years ago, this equipment has been chosen for practically all Indian tunnelling projects of any size.

Here is an unbeatable *lightweight* drilling unit that has extensively replaced the heavy bar-rigged drifter. Atlas Copco rock drills and Sandvik Coromant tungsten-carbide-tipped steels have brought *faster drilling times, smoother progress at lower cost* on projects from Australia to Canada, Norway to Brazil This drilling equipment was the obvious choice for India's mighty Bhakra-Nangal project.



Entrance to one of the two 2,500-foot-long diversion tunnels, each with a diameter of 50 feet, started with other equipment and finished with Atlas Copco drills and Sandvik Coromant steels.

The Prime Minister of India visits the Bhakra-Nangal project. Costing £113,000,000, it is one of the biggest power and irrigation schemes ever planned.

The services of the Project Department of Atlas Copco, whose job is to draw up drilling patterns and to advise on tunnelling and mining techniques, is at the disposal of mining engineers and contractors everywhere without obligation.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

For further technical information about Atlas Copco Rock Drills and Sandvik Coromant Steels write to the most convenient of the addresses given here:

UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx.; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia S.p.A., Viale Marche 15, Milan.

CANADA, Atlas Copco Canada Ltd., Montreal, A.M.F., P.Q.; AUSTRALIA, Atlas Copco Australia Pty. Ltd., P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty.) Ltd., P.O. Box 504, Benoni, Transvaal; U.S.A., Atlas Copco Pacific, Inc., 930 Brittan Avenue, San Carlos, California; Atlas Copco Eastern, Inc., P.O. Box 2568, Paterson 25, N.J.

Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

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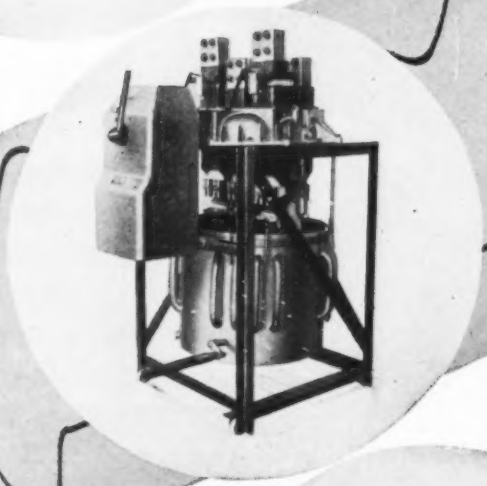

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tensioni fino a 35 kV
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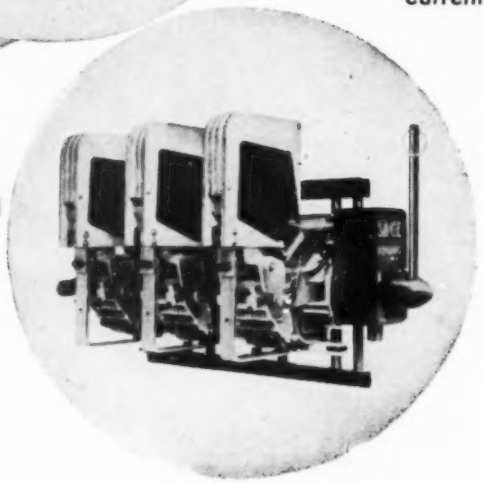
currents up to 12 000 A



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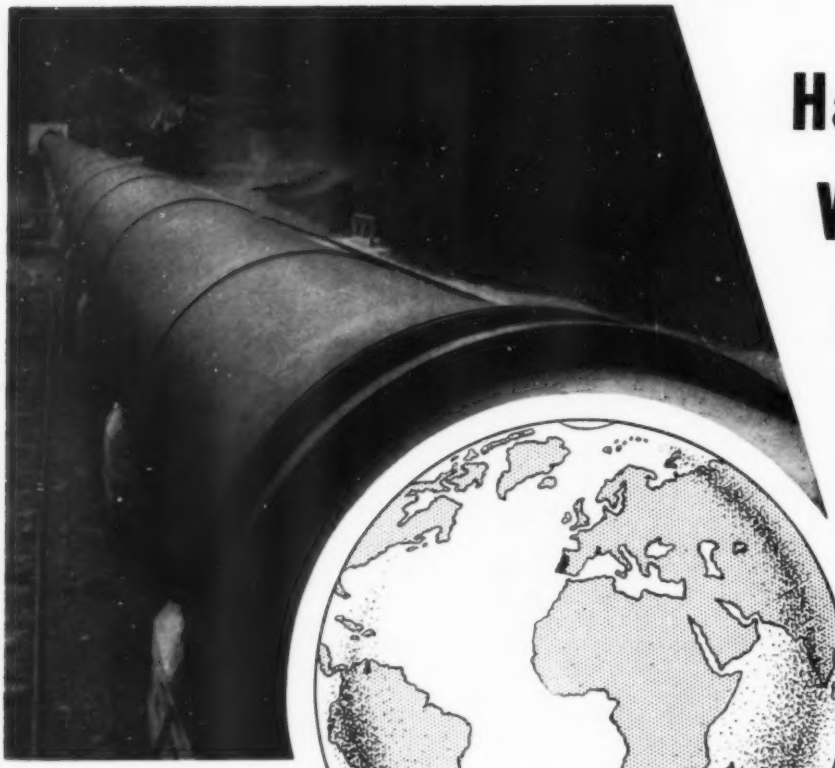

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Illustration shows Hydro-Electric pipeline—erected, welded and tested by South Durham for the Hydro-Electric Project at Vila Nova, Portugal.

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the Porcia Palace at Spittal on the Drau, one of the most beautiful 16th century Italian Renaissance courtyards, a typical example of cultural interchange between Italy and Austria.

Photo : Österr. Nationalbibliothek

. . . and that is

a 50-MVA power transformer at Lienz, interconnecting the Italian and Austrian Grids, a typical example of 20th century power interchange between Italy and Austria.

Photo : Mariner

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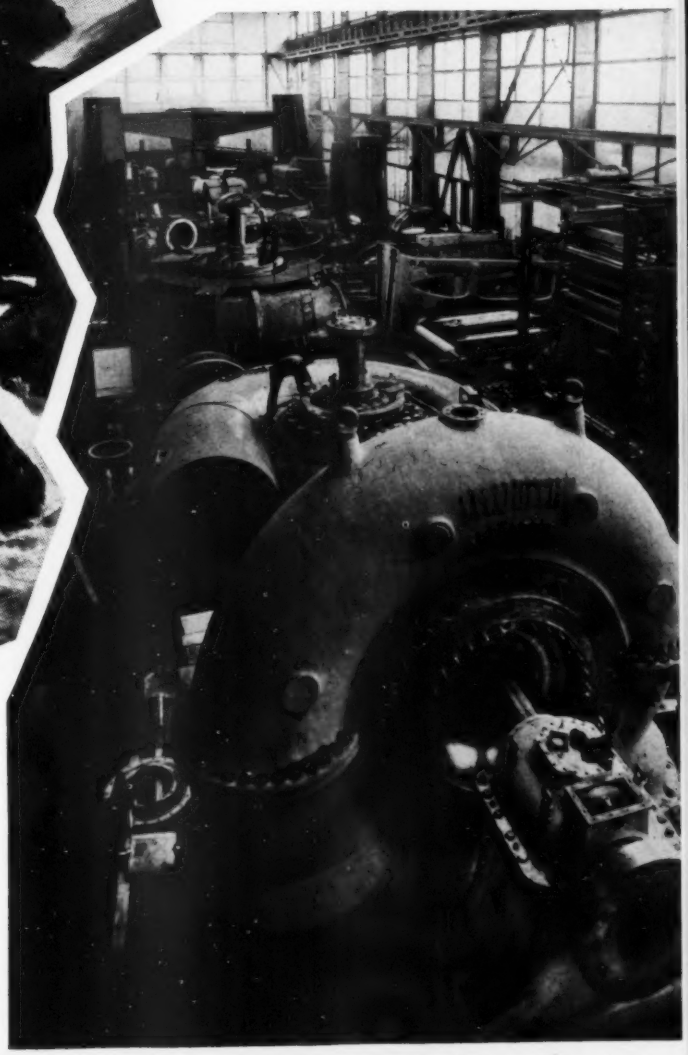

View in erection shop, showing assembly of large Francis turbines. In the background, the giant turning mill.

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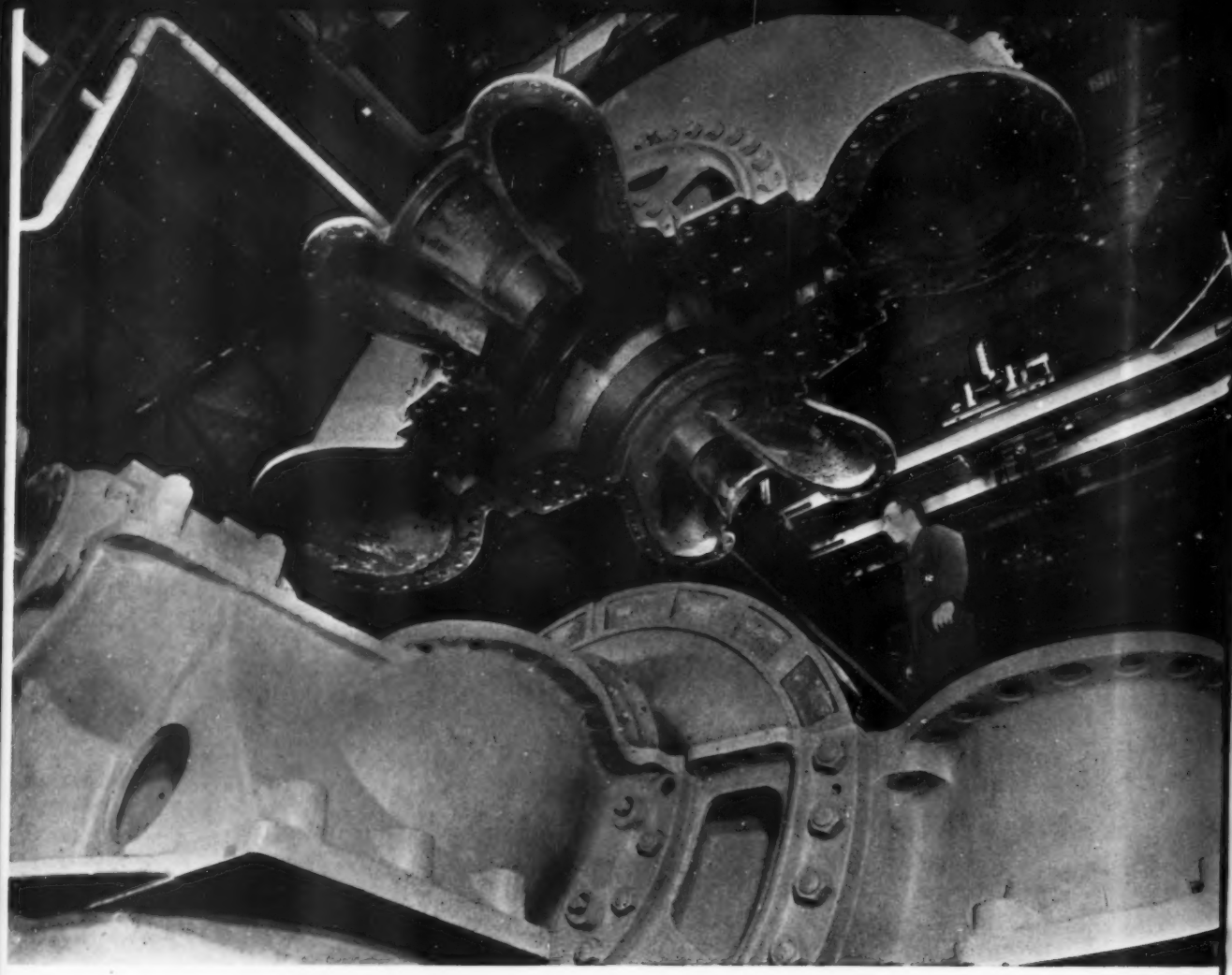

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One multi-stage centrifugal pump absorbing 3,000 H.P.—head 340 m; discharge 560 lt/sec.- speed 1000 r.p.m.; for Foce Ponale Power Station, Italy

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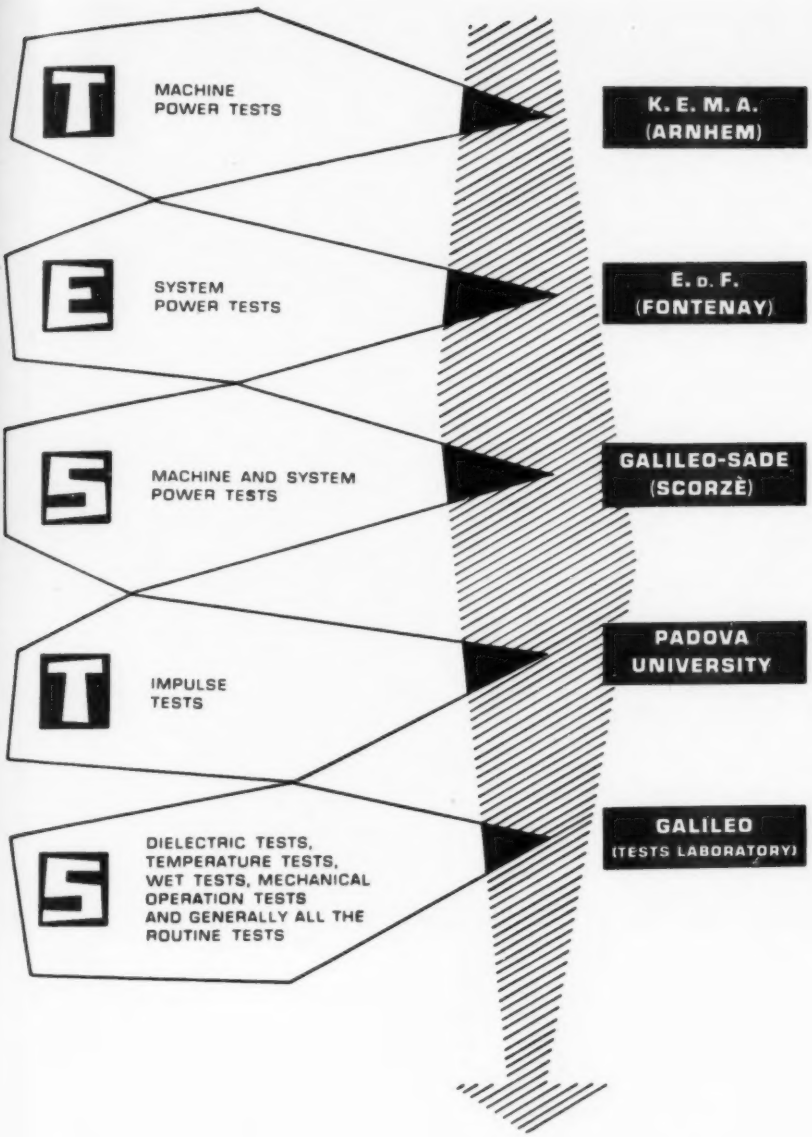

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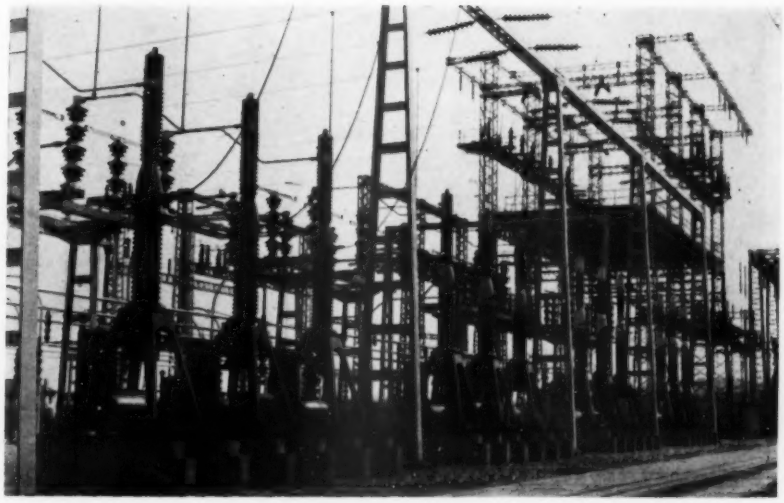

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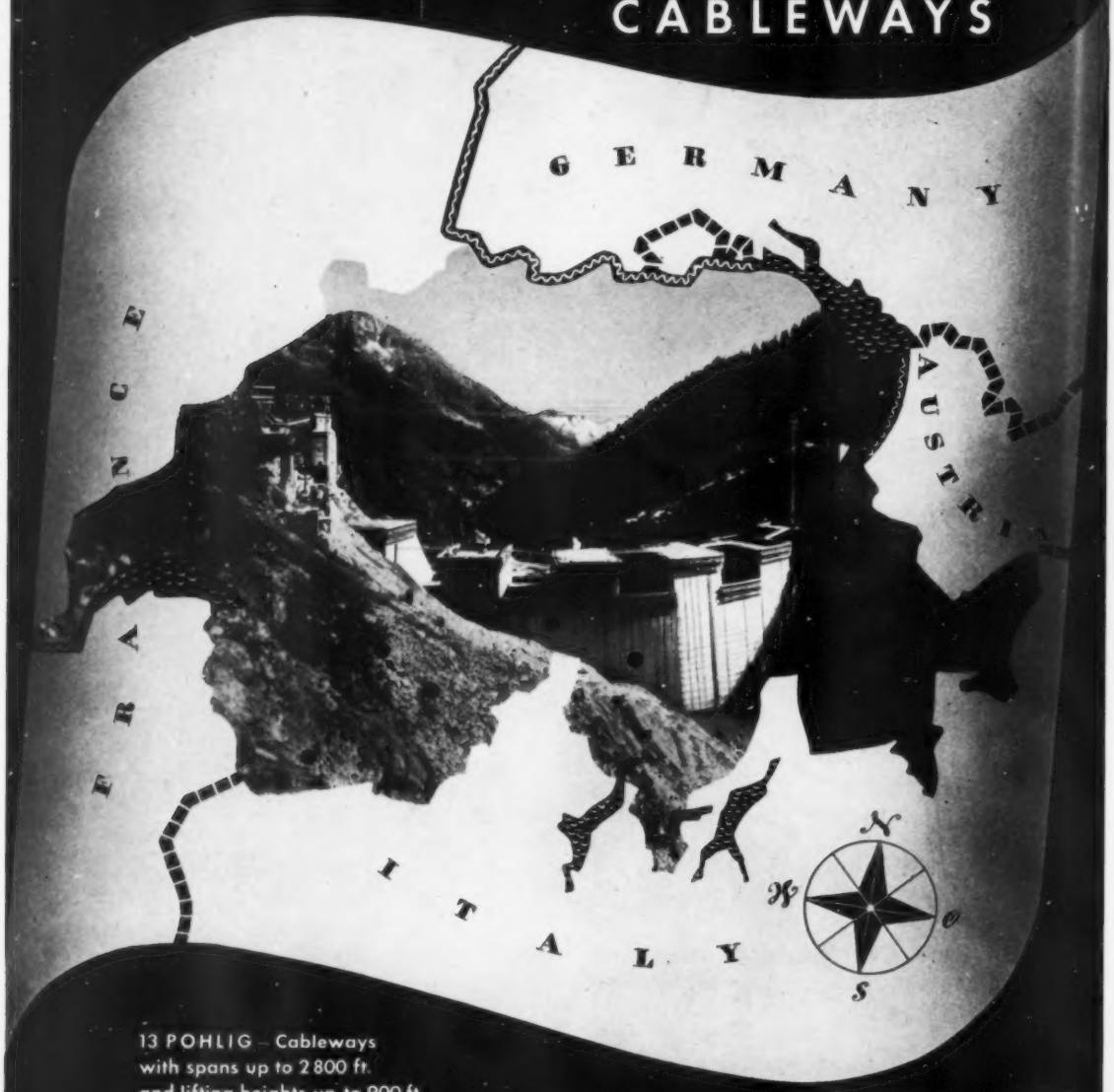

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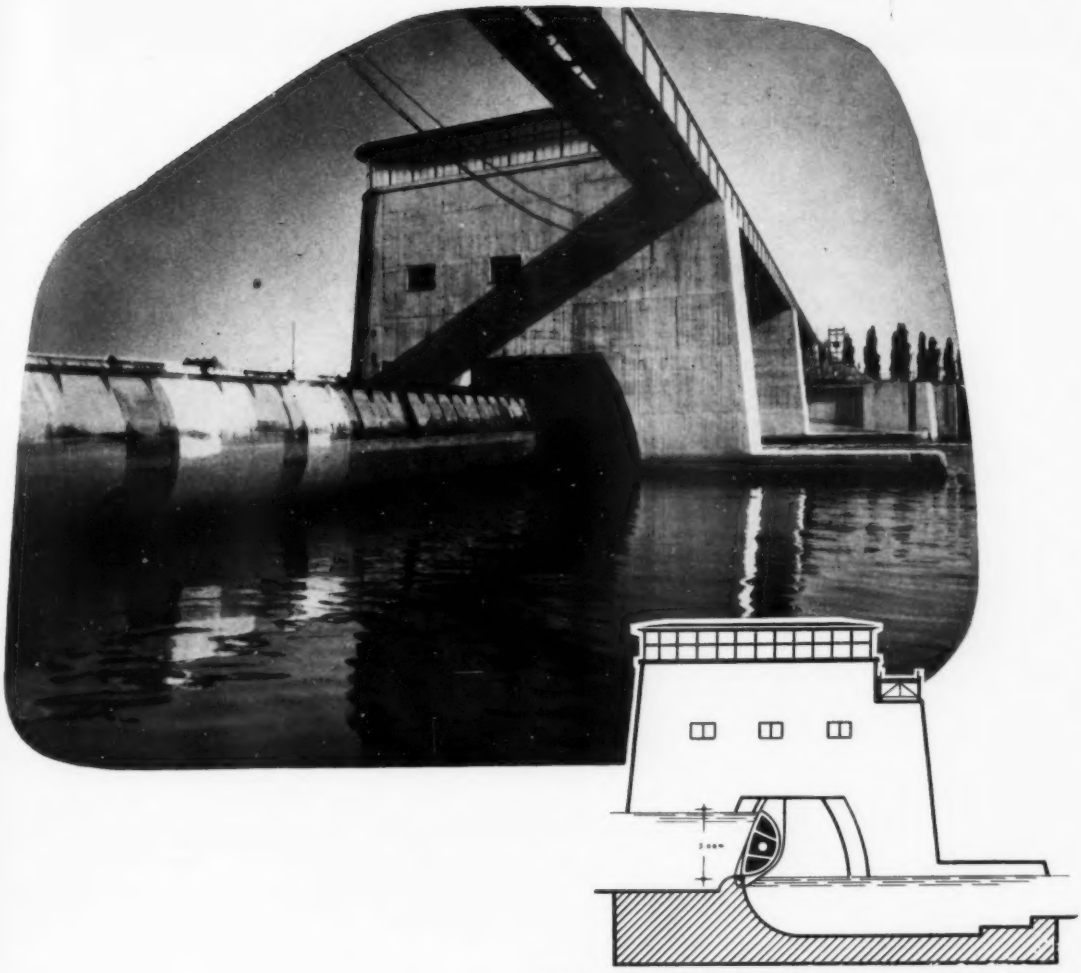

A height of retention of 5 metres and 40 metres clear width are the characteristic dimensions of the largest fishbelly flap hitherto built. This type of gate is the result of elaborate tests in MAN's own laboratory, where actual site conditions can be reproduced to scale.

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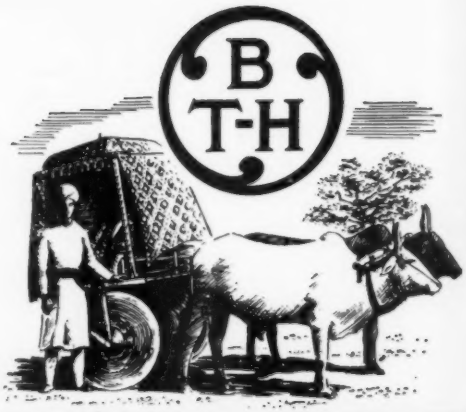
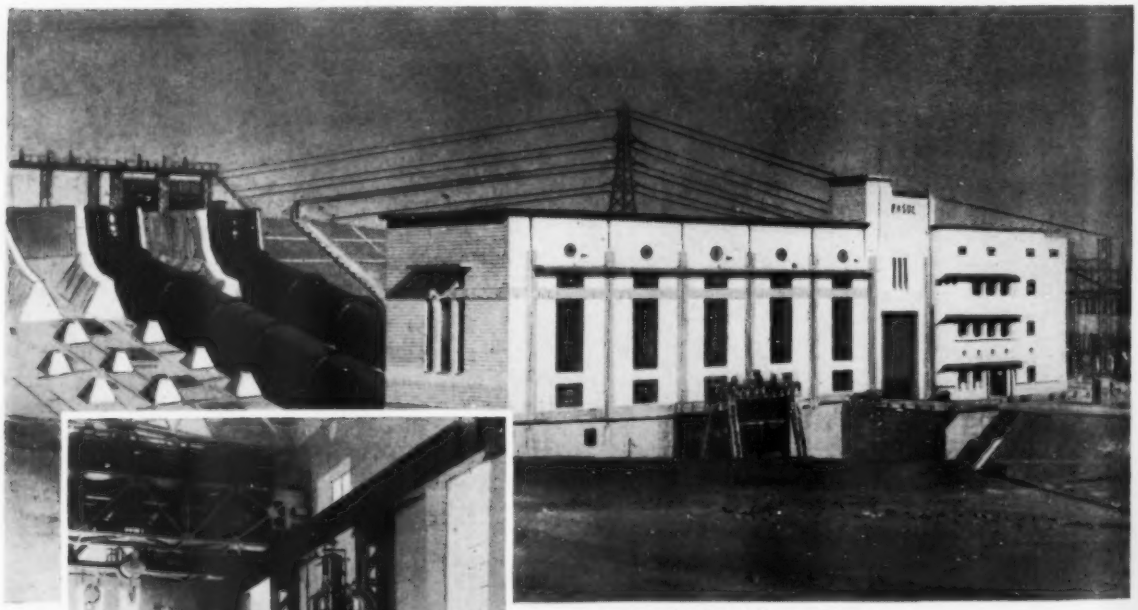
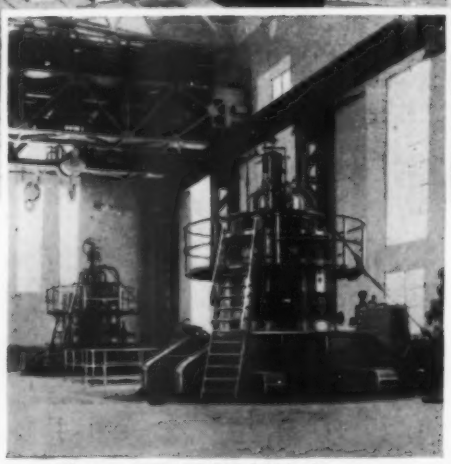
West Punjab, with five rivers and fertile plains, produces much of Pakistan's cotton, sugar, and cereals. Until recently it depended on India for electric power, but now the Rasul Hydro-electric Station, in the Gujrat District, generates power from the drop between the Upper and Lower Jhelum Canals. This undertaking will help to electrify twenty-eight towns, and power the tube-wells in the Chaj and Rachna Doabs, where thousands of acres have been rendered unfit each year by rising water-tables and sub-soil salinity. BTH equipment plays a major part in this scheme, helping again to harness natural resources to the betterment of the community.





A view of the Rasul Power Station



The two BTH 12,500 kVA alternators

For the Rasul Power Station, BTH supplied the two 12,500 kVA alternators, driven by Boving Kaplan turbines. BTH also supplied the 132 kV switchgear and the 132/66 kV transformers, together with the 5,000 kVA synchronous condensers at Lyallpur Sub-station.

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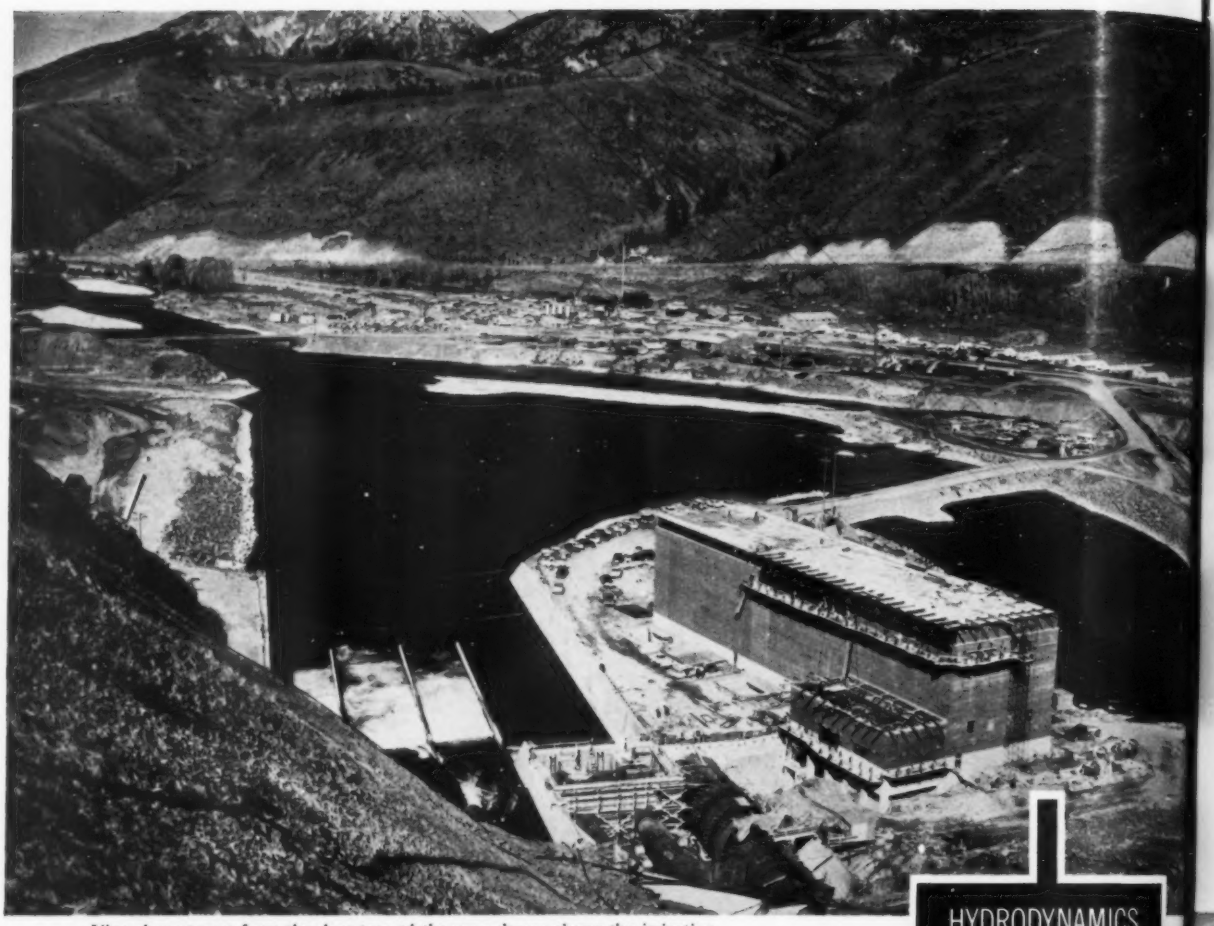

View downstream from the dam toward the powerhouse shows the irrigation bypass (left), penstock (center) and tail-race canal (right). *(U.S.B.R. photo)*

HYDRODYNAMICS

Mile-High SMS-Francis Turbines soon to deliver power at Palisades

High on the south fork of Idaho's Snake River, the first of four SMS-Francis turbines at Palisades Dam is scheduled to go on the line in 1956. The Palisades Dam, which is the Bureau of Reclamation's largest earth-filled dam, is primarily an irrigation project. The dam will have a crest length of 2,100 feet, rise 270 feet above the streambed, and provide a storage reservoir some 20 miles long and 3 miles wide.

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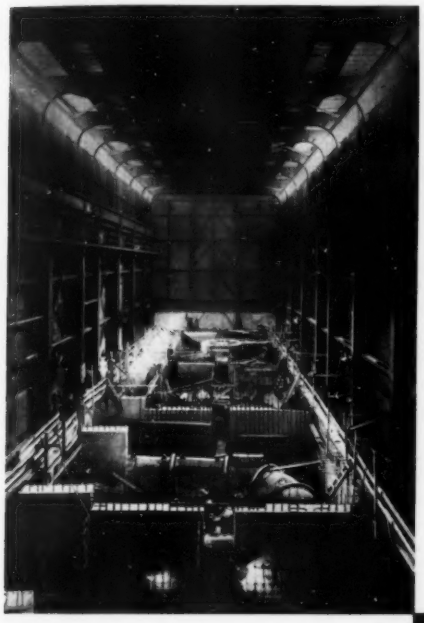
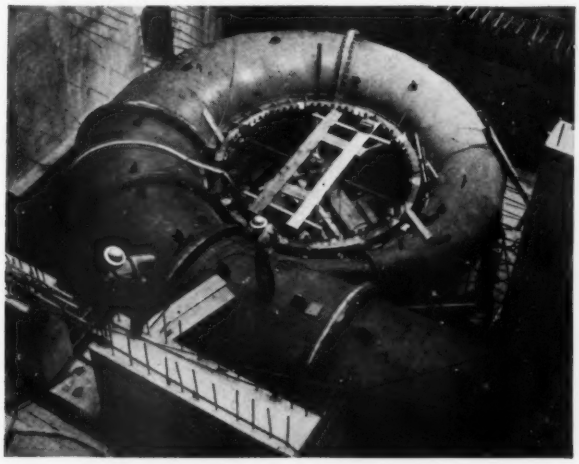
Inside view of the powerhouse, with the pit for Unit #1 in the foreground, and Units #2, 3 and 4 in various stages of construction to the rear. *(U.S.B.R. photo)*



Scroll cases for the Palisades turbines are shop-welded steel plate construction. *(U.S.B.R. photo)*



Final check assembly of Unit #2 – a complete scroll case, pit liner, distributor gates and operating mechanism – is made in SMS shops prior to shipment to the site.

Welding a flange to a section of Unit #3's spiral steel case. SMS shops are completely equipped to fabricate weldments of the largest types.

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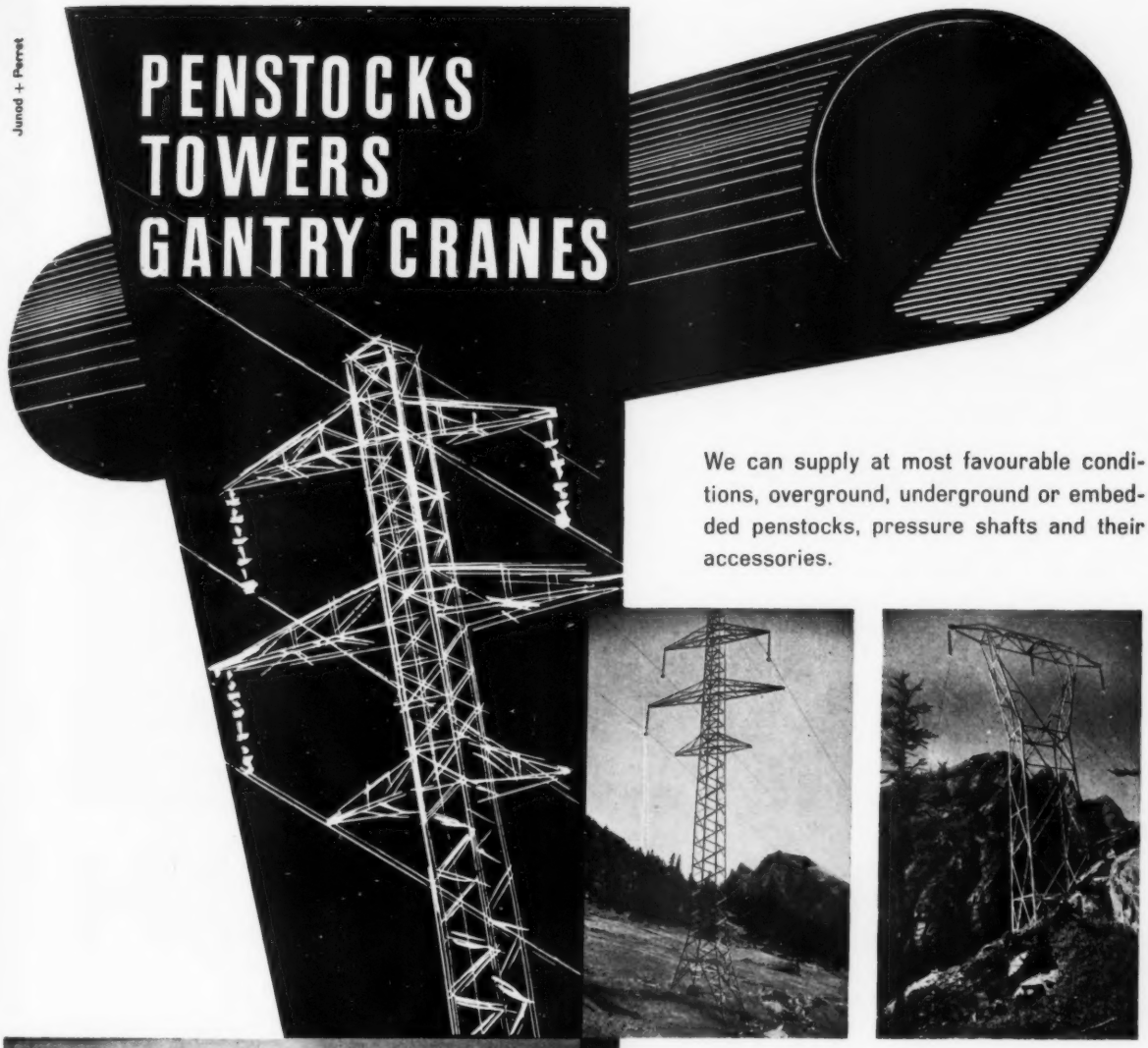

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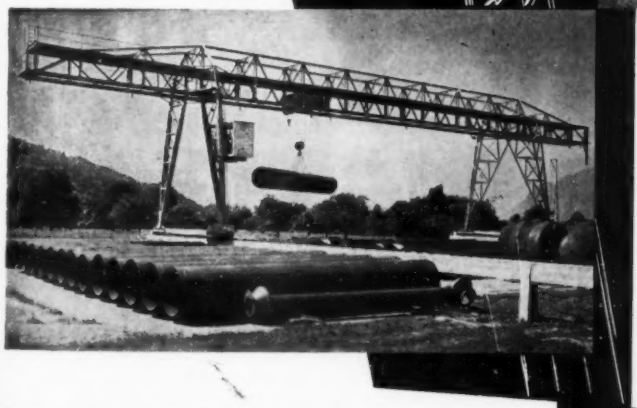

Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

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The Merila Barrage is part of the Low Tana Hydro Electric Development in Kenya, which has been designed and constructed by Balfour Beatty for the East African Power and Lighting Co. Ltd.

The photograph of part of the barrage, which diverts water into the headrace tunnel, shows one of the 37′ 6″ span automatic control gates starting to open.

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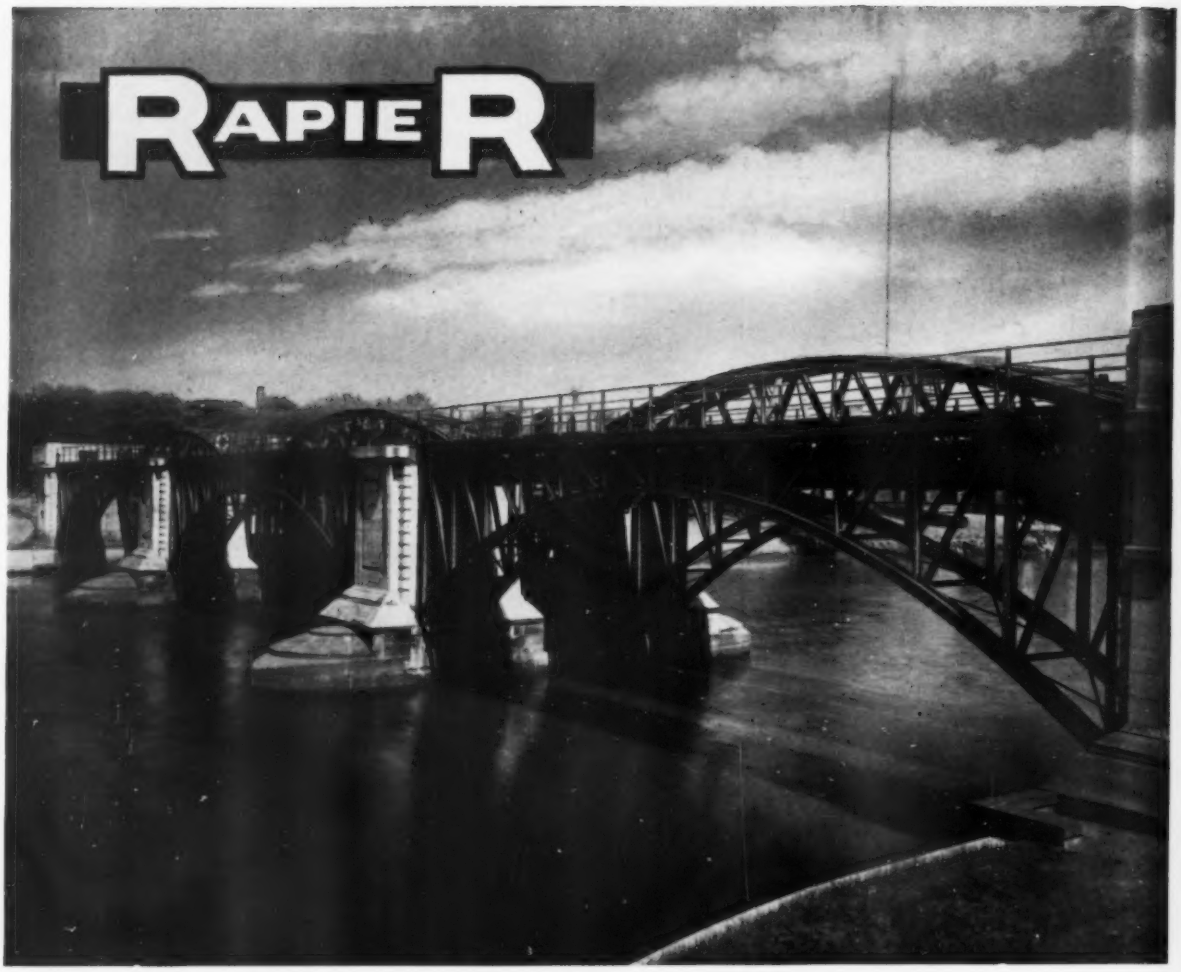

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n. réf. / / /

à rappeler dans votre réponse

LABORATOIRE DAUPHINOIS D HYDRAULIQUE

GRENOBLE, le January 15th 1956.

OBJET :

V réf. :

Dear Sir,

The Laboratoire Dauphinois d'Hydraulique, which until recently was a branch of the Etablissements NEYRPIC, has for some time been developing and extending its activities. This trend led, in March 1955, to the formation of a new company specialising in hydraulic studies. Its object was to take over progressively all the functions of the Laboratoire Dauphinois d'Hydraulique. We are now able to tell you that this process was finally completed on 1st January 1956.

SOGREAH is a company of Consulting Engineers, specialising in hydraulic techniques in particular and in fluid mechanics in general, with every facility for supporting its theoretical work with laboratory tests.

Since the personnel of the Laboratoire Dauphinois d'Hydraulique of the Etablissements NEYRPIC has been transferred almost in its entirety to our company, the same staff will be at your disposal to deal with any problem that you may require solved.

We shall continue to do all in our power to merit your confidence.

Yours faithfully.

Le Directeur Général Adjoint, — *Le Président-Directeur Général,*

G. Sauvage de St Marc — Pierre Danel

Gaston SAUVAGE de SAINT MARC — Pierre DANEL.

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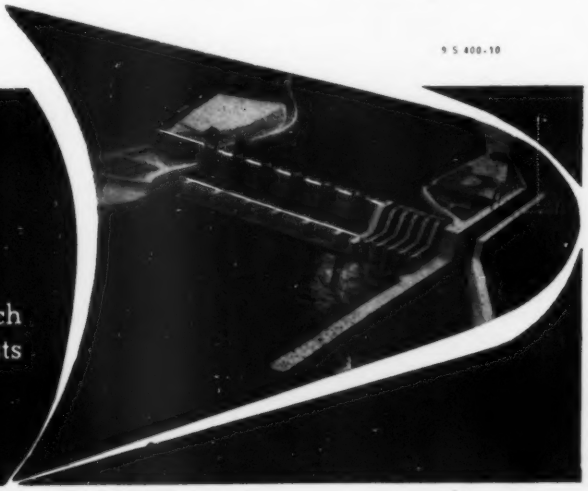
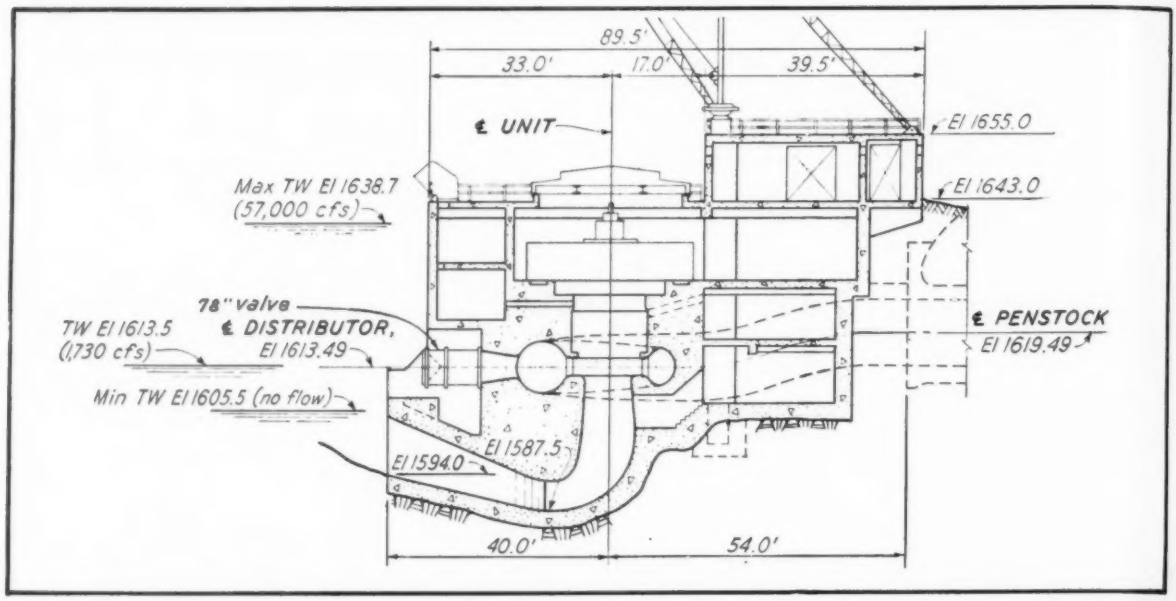


Theoretical and experimental research and studies — Scale model tests

TVA Installs *Another* Leffel Turbine

Nottely Dam Power Plant — a progress report as of the end of 1955



Completely assembled turbine except for riveted scroll case.

Powerhouse excavation and draft tube forms in place.

Assembled scroll case in position from above.

In the new hydroelectric power plant on the Nottely River near Murphy, North Carolina, the TVA is now completing the installation of another efficient Leffel turbine.

Nottely Dam, of the rock and rolled earth fill type, was completed in 1942, without a power unit. Installation of the No. 1 power unit was authorized in 1951 and a Leffel turbine was selected to drive the generator.

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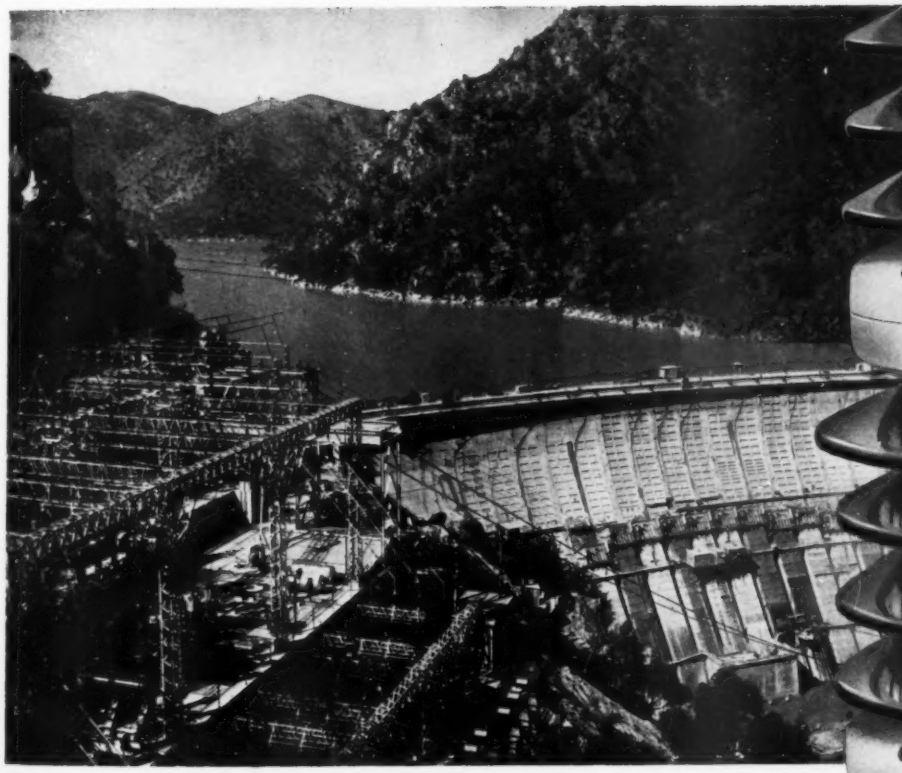

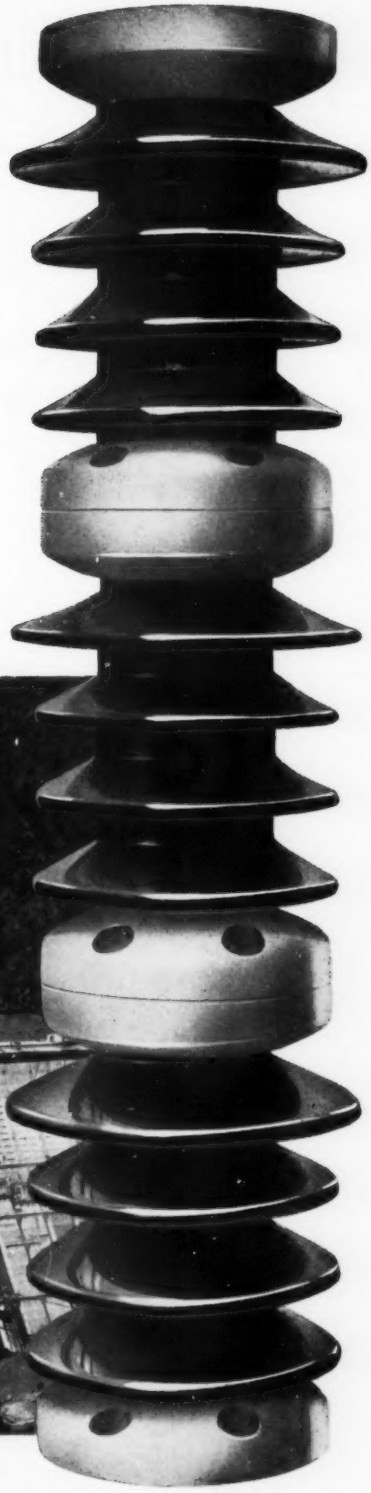

The Burrinjuck 132 kV Switching Station was equipped with Cylindrical Post Insulators type P.703. This is one of many stations on the New South Wales Public Works Department system equipped throughout with S.P.P. Post Insulators for 110 kV and 66 kV.

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Northern outfall works at Beckton

View of Supply Channels from Screen House with Primary Sedimentation Tanks in background.

This contract, recently completed for the London County Council, comprised the construction of Penstock Chamber, Main Supply Channel, Screen House, Supply Channels, Distribution Channels, sixteen Sedimentation Tanks, Sludge Pumping Station, Effluent Culverts and outfall works.
The works, which are designed to deal with an anticipated flow of sewage of 200,000,000 gallons a day. were constructed almost entirely in reinforced concrete.
The foundation work included the driving of 8,500 precast concrete piles. Sulphate-resisting cement was used for all the piling work.
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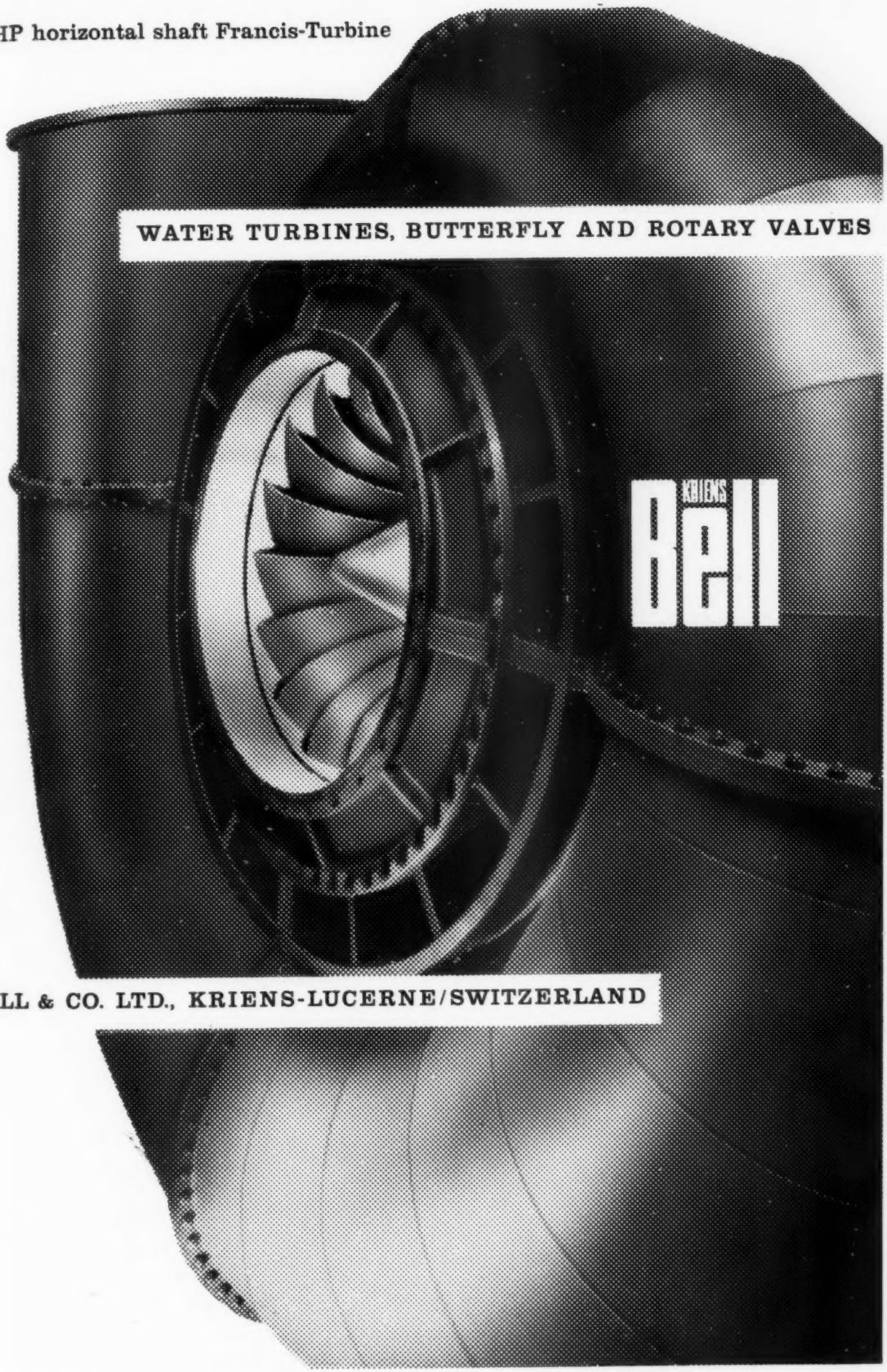

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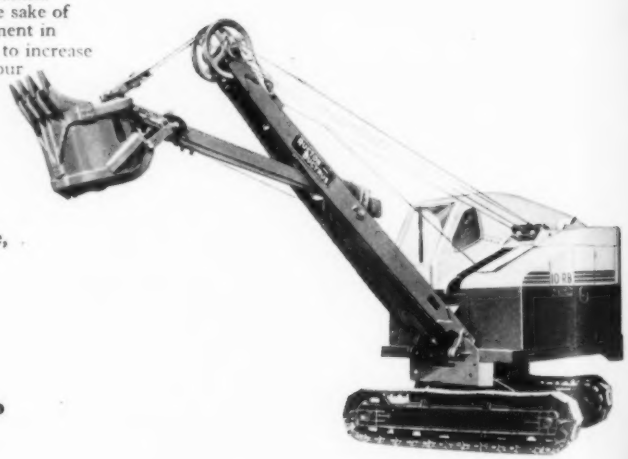

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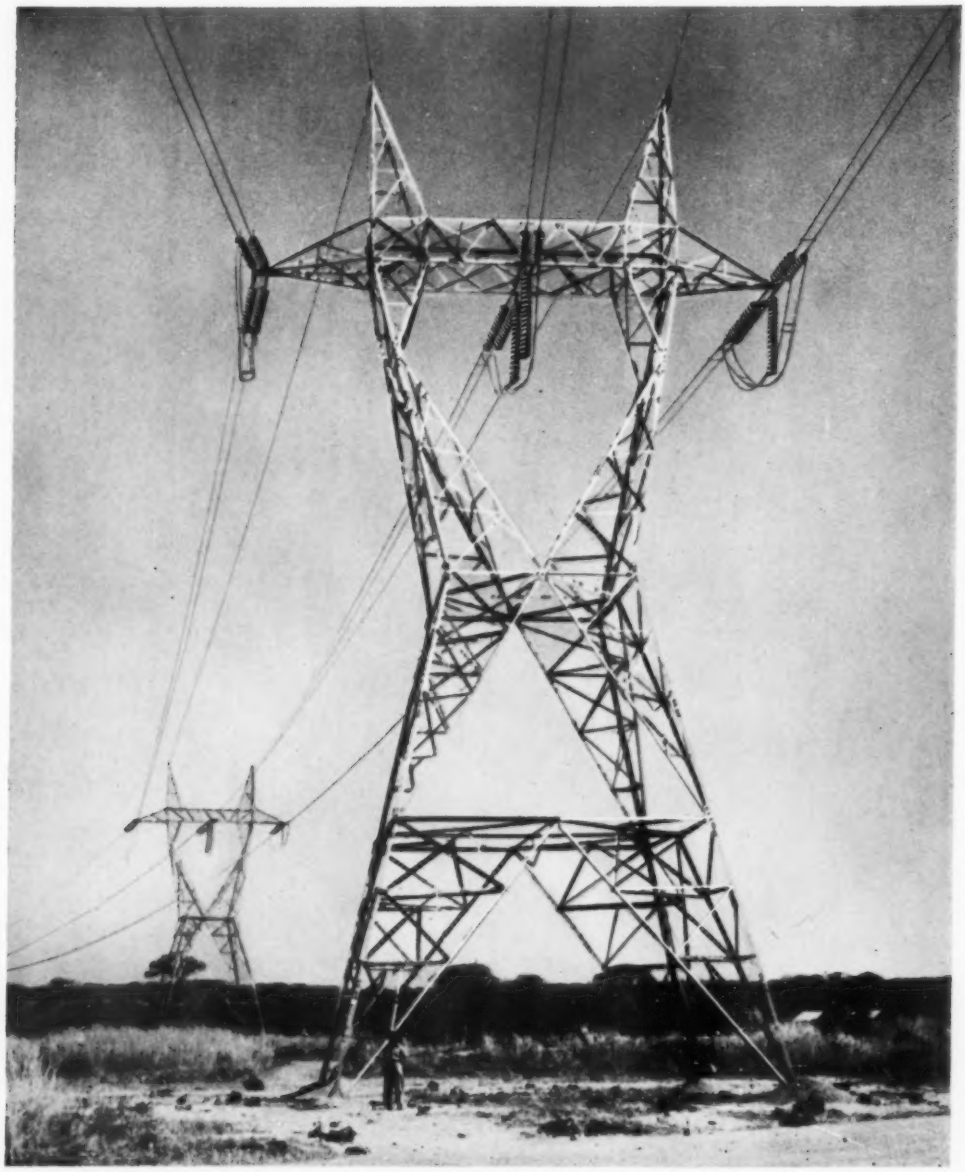

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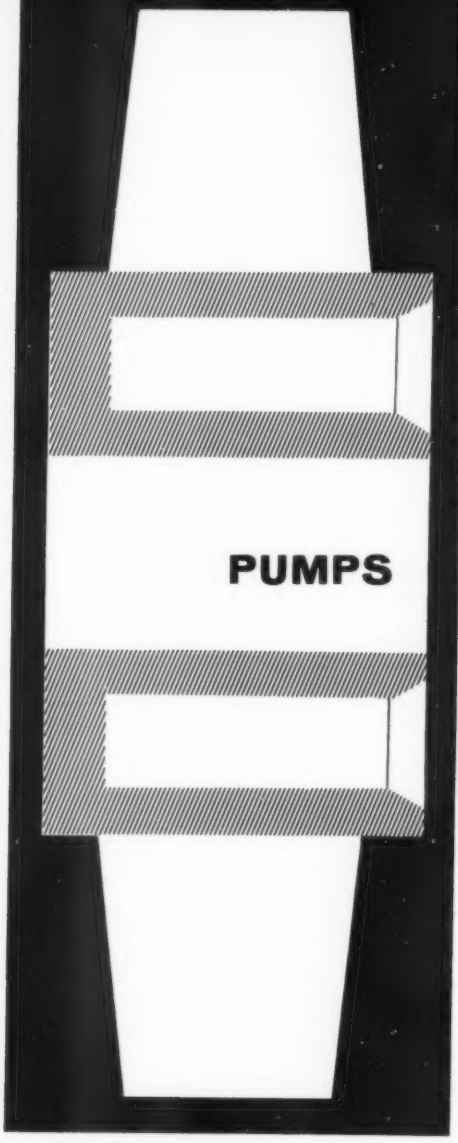

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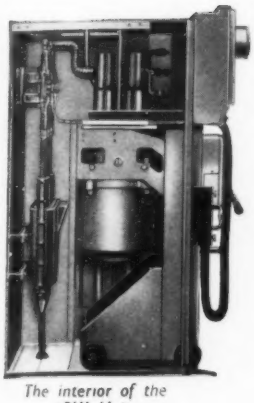
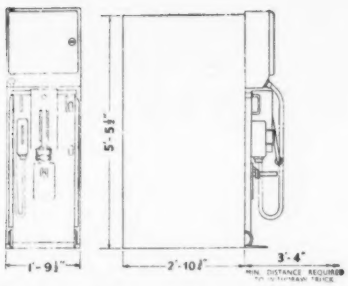


The interior of the BV' Unit



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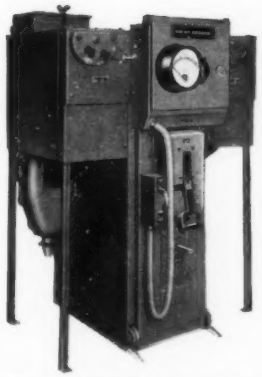

BV switchgear is designed for extension to small or other switch units/isolators as required. The illustration shows a BV unit combined with a type IB isolator.

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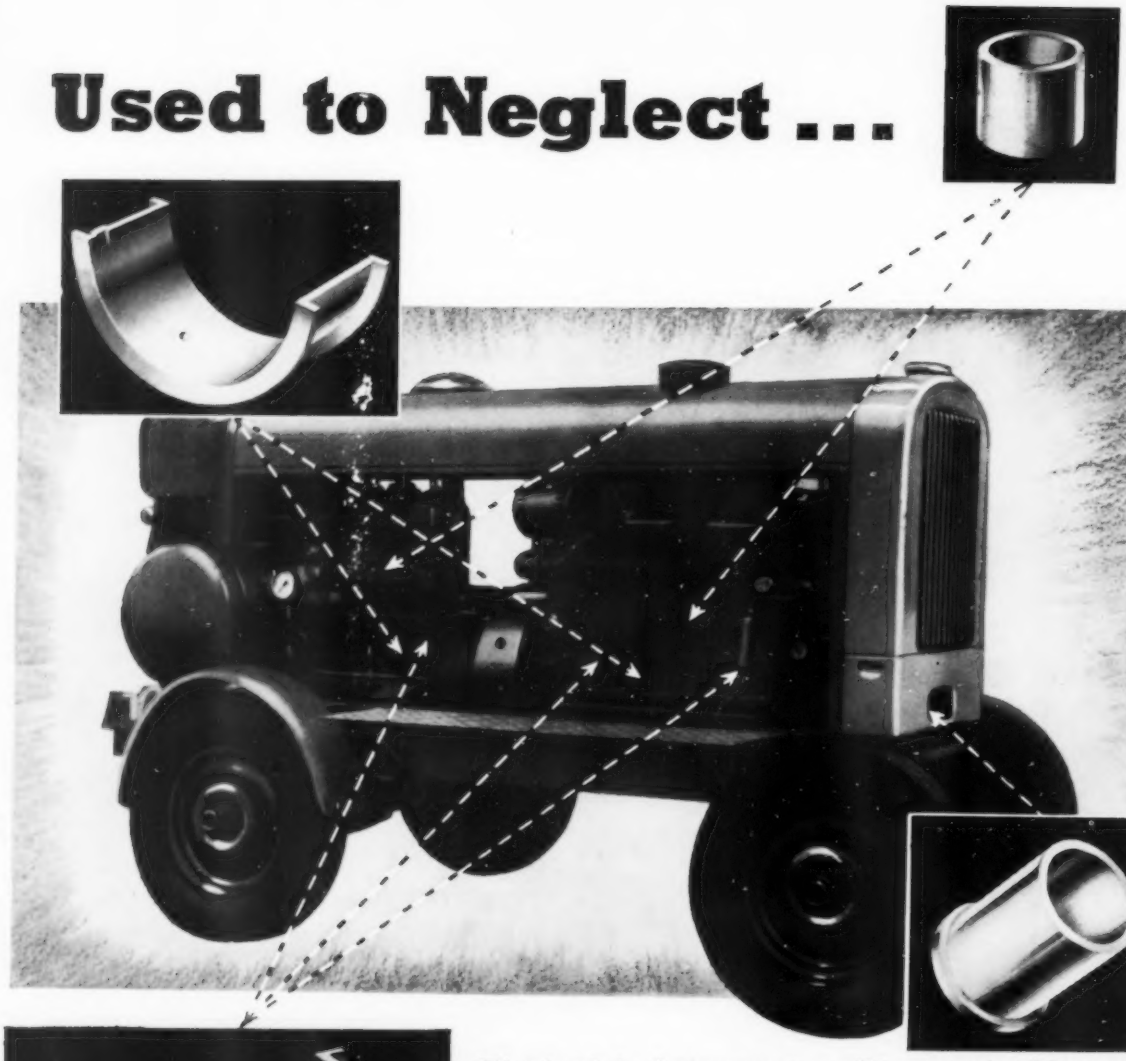

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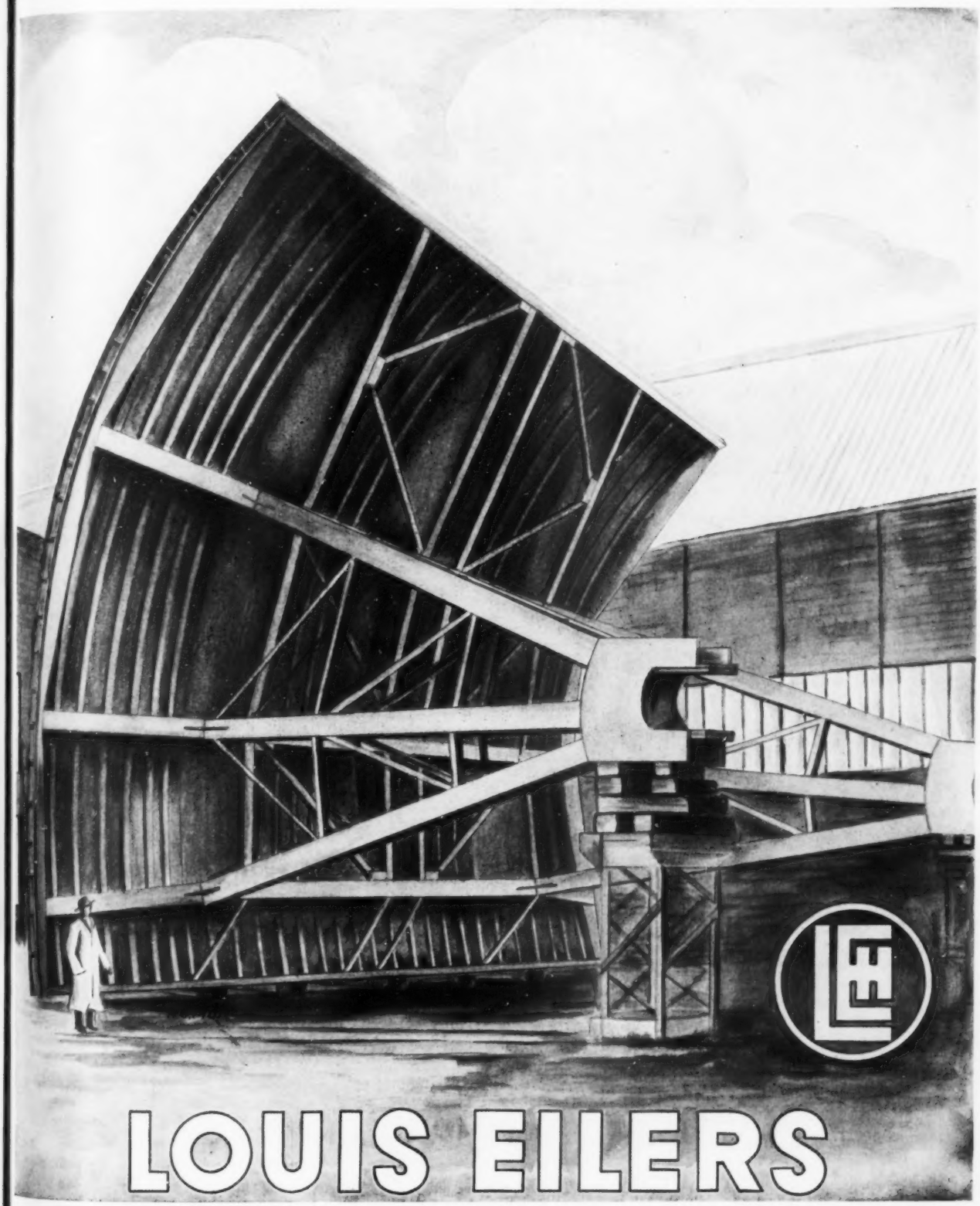

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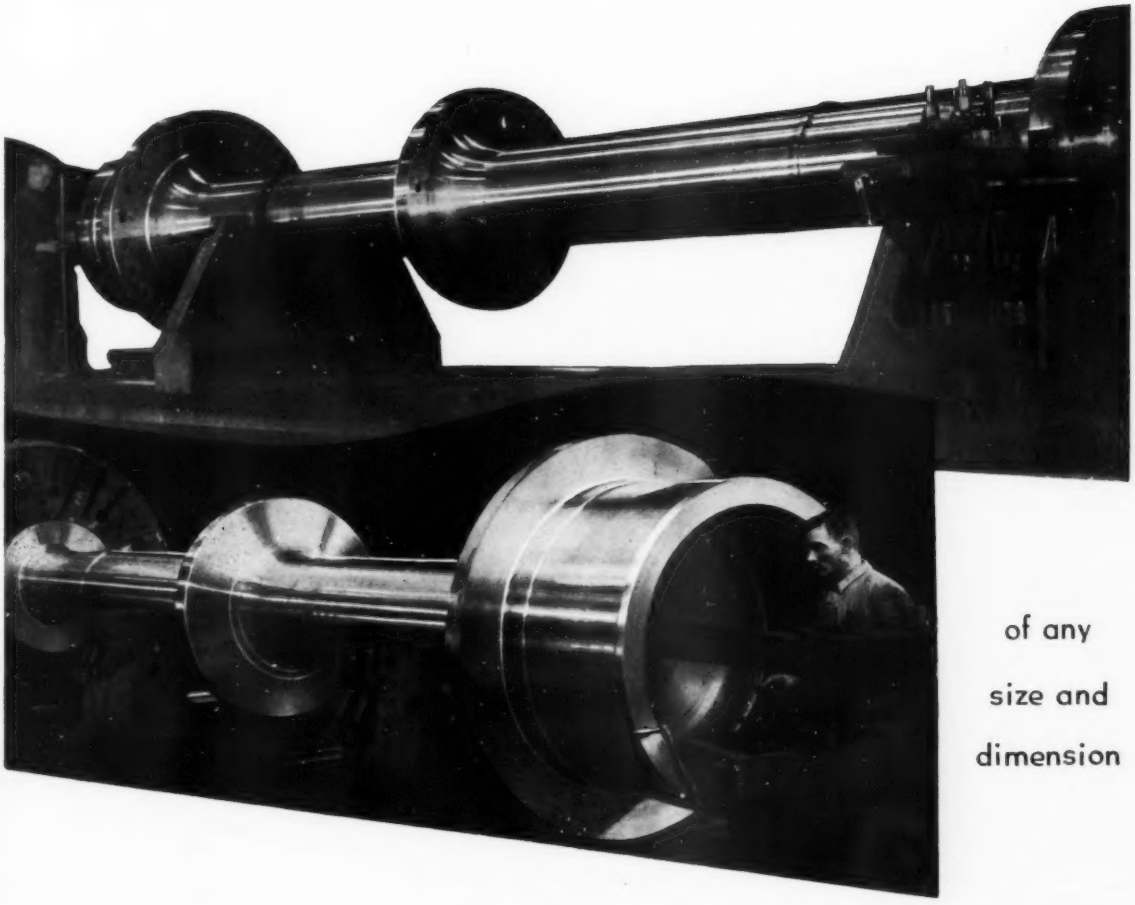

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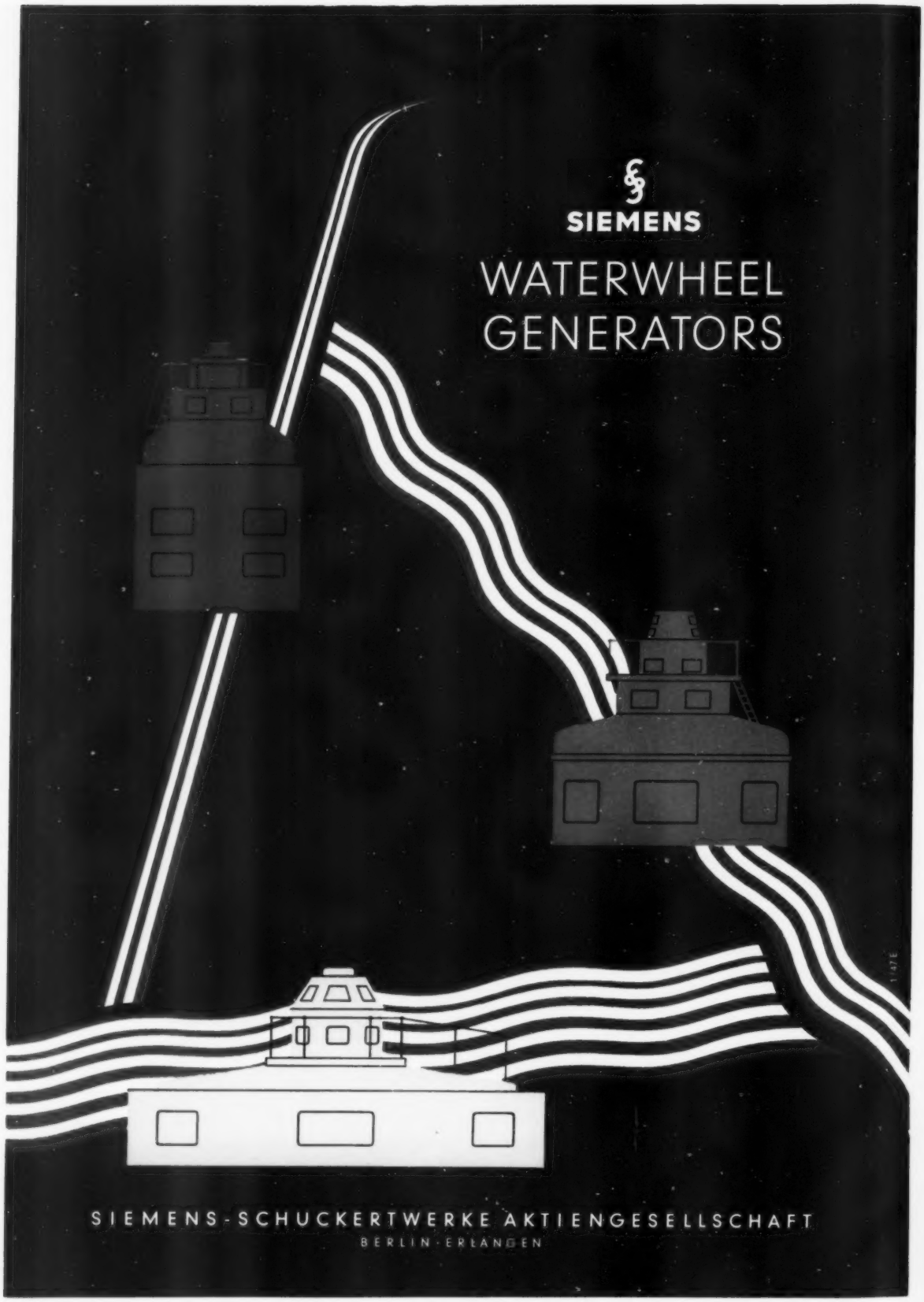
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Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

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The Outlook for Hydro Power

IN all industrialised countries—and what literate country, in these days, is not actively attempting to achieve that status?—there are influences at work which, viewed in a historical perspective, will inevitably lead to political and economic pride of position being awarded to the nation with the greatest supply of available energy. In the long run this must override all other considerations, because all else—even the supply of the food needed to sustain life and the water required for health—is becoming more and more dependent on electrical power. Large populations, regrettably enough, would be politically impotent without the energy needed to create the scientific instruments of warfare nowadays essential if they are to put mailed fists in the velvet gloves of diplomacy; and in trade, the race goes to the swiftest to electrify.

The influences tending almost to deify electrical energy as the primary need of civilised communities may be classified under several headings. First, the attitude of labour towards the community is fairly rapidly leading to a condition where the very high wages now demanded can sway the balance between economic stability and export-import bankruptcy. This is not to suggest that it is wrong for labour to demand its due share of the fruits of industry, but the tempo at which those demands are advanced must keep step with the advance of productivity, and when this synchronism is destroyed the whole economic machine is thrown out of gear. The only answer here is to reduce the wages cost of a manufactured article, and here electrical automation comes into its own. But an "automatic" factory (one where the minimum of manual labour is necessary) uses far more electrical energy per unit of output than is the case in the more usual plants nowadays in service. As an example, semi-automation of one large section of a particular automobile plant put up the electrical maximum-demand figure in a ratio of five to one per vehicle sent out. Fierce international competition will force automation methods on industrialists everywhere, even if there is opposition from organised labour. More and more power will be needed to meet the situation.

A second great long-term factor relates to the progress made by the medical profession in saving and prolonging life. The populations of countries where very high infantile mortality rates were formerly accepted as normal have increased enormously in the last few decades. As an example of this influence at work, mention may be made of the effect of a vaccination campaign carried out by a United Nations Agency in an underdeveloped Central American country. Before the campaign, twenty infants in every hundred born died within a year; after it, only five succumbed, over a three-year statistical period. All these new mouths to feed are supplemented by the old people, who, in general, live longer due to medical care. But the infants saved from early death pose another problem for the energy planners. Each successive generation will demand a standard of living—based on electrical energy—which starts to improve from a level even higher than that attained by the preceding generation. A newly married couple, each having lived in houses where one electric lamp was regarded as ample in one room, will tend to plan their own new living quarters on the basis of three or four lamps per room; and they will demand as of right all the other electrical domestic amenities nowadays regarded as essential.

Sufficient food to supply growing populations can only be provided if artificial fertilisers are available in great quantity, and only electrical energy can provide them. Mechanised agriculture and horticulture lean heavily on electrical energy, both on the farm and in the factory where the agricultural machinery is made.

All these influences, then, will tend to make the providers of electrical energy the essential servants of any community. Where can they look for their raw materials? It is becoming abundantly clear that within the next three decades there will be a concentration on two, and only two, major methods of electrical-energy production—nuclear energy and water power. The one enables any country (if it can afford the capital cost) to establish a power plant almost anywhere where cooling water is available, and the other, though

limited to countries with suitable topography, provides everlasting power with the minimum expenditure of technical effort, once the constructional project is completed.

The wasteful procedure of mining coal at great cost and no little danger, hauling it over long distances, and then being forced to throw two-thirds of its heat content away into cooling towers or rivers, will become increasingly difficult to justify. The mineral is too precious to waste; its byproducts are too badly needed to allow them to disappear as noxious gases up power-station chimneys, and the heat rejected by the thermal power cycle should be increasingly conserved for industrial process-heating or district-heating purposes.

After the next four decades, the use of solar power may well begin to become practicable on a larger scale, but the problems of intermittent availability of sunlight will lead to a great need for storage of energy, and unless the fuel cell is developed to a degree so far thought to be unlikely, the pumped-storage hydroplant will be even more vital to the proper operation of the world's power systems.

In any case, whatever developments may take place in nuclear or conventional thermal power generation, the position of water power will remain secure. Apart from the future possibility of harnessing solar power, water power is the only source of energy that does not utilise a wasting asset, and furthermore, its characteristics make it the ideal medium to correlate with thermal generation where such a partnership can be shown to be economic.

The World Power Conference, holding its fifth meeting in Austria this year, forms a focal point for discussion of the factors briefly set out above, and it could not be held in a more appropriate setting from the hydro-electric engineer's point of view. Austrian developments in this field are well known, and the Ybbs-Persenbeug and Kamp Valley plants (the former described elsewhere in this issue and the latter including a 40 MW pumped-storage scheme) to be visited by the delegates are typical of the energetic and highly skilful way in which Austrian engineers are making the best possible use of their natural resources. The high level of precipitation and the great differences of head to be found in the waters of the Austrian Alps render Austria a most fortunate country in regard to potential water power.

Another possibility that is of increasing interest to hydro-electric engineers is tidal power. After many years of discussion in many countries it now appears certain that within a few years the harnessing of tidal power will become an accomplished fact, and the conference to be held this month in Paris under the auspices of la Societé Hydrotechnique de France is particularly opportune. Current trends in thinking about tidal power are well summarised in an article, the first part of which appears elsewhere in this issue, by a German engineer who has made a life study of this question.

Electrical transmission problems are of the utmost concern to the hydro-electric engineer, and that invaluable biennial function, the CIGRE Conference, also being held this month, is to be welcomed. Hydroelectricity is becoming increasingly bound up with achievements in the field of electrical transmission.

Truly this is a month of conferences, and in future issues we hope to give some account of all of them.

East Kilbride Laboratory Model

A 1 : 48 scale model of the new D.S.I.R. Hydraulics Laboratory at East Kilbride, Glasgow, was on view recently at the Institution of Mechanical Engineers. Tests on water-turbine models and on pumps under cavitation conditions will be carried out on a closed circuit which will accommodate turbine models up to 250 h.p. and 20 in. runner diameter at heads ranging from 10 to 200 ft. and pumps with inputs up to 350 h.p., heads up to 600 ft. and deliveries up to 7,500 g.p.m. For low heads the water will be circulated by a variable-pitch axial-flow pump, and for high heads by a centrifugal pump. The temperature, pressure and air contents of the water are controlled, and any air bubbles produced by cavitation are reabsorbed by subjecting the water to high pressure by passing it through an underground tank 12 ft. in diameter and 60 ft. deep.

The main test bay is of the open-circuit type and contains a 60,000 gallon covered sump with removable decking and underwater illumination. A flow of 32 cusecs at a constant head of 45 ft. can be maintained from an overhead tank supplied by two service pumps, and variable heads between 10 and 40 ft. can be obtained from a second tank with a telescopic weir. Friction and flow-measurement tests can be conducted with the aid of a 700 ft. loop of 20 in. diameter pipe, and pipelines of 8, 14 and 18 in. in diameter are available for flowmeter research.

An aerodynamics laboratory and an oil and special fluids laboratory are also included in the facilities.

Cheakamus Contract Awarded

THE contract for the construction of the power house in British Columbia Electric Company's Cheakamus hydro-electric project has been awarded to Mannix Ltd. Mannix underbid three other firms for the $2,500,000 contract which calls for grading and footings for two 1,700 ft. steel penstocks, and for a 230 kV switchyard, in addition to construction of the power house which will produce 190,000 h.p. by the autumn of 1957.

Other phases of the project include a 6¾ mile tunnel to divert water from the Cheakamus River into the Squamish and a large dam to back up waters of the Cheakamus creating an artificial lake over surrounding marshland.

In addition to the $2,500,000 construction cost, the power-house work will involve installation of $4,000,000 worth of power-house equipment.

Indian Station Opened on the Sarda Canal

THE 41,400 kW hydro-electric power station on the Sarda Canal at Khatima in the Naini Tal district of Uttar Pradesh was opened by the State's Chief Minister, Mr. Sampurnanand, on April 27. It cost Rs. 12,64,70,000 and is the largest hydro-electric power station in the State. It will serve eleven central districts of the State and augment supplies to the Ganga grid. It is expected to yield an annual revenue of about Rs. 73·3 lakhs and, when loaded to full capacity, will generate about 112·4 million units per year. The construction of the civil works of this power station was started in 1945-46. The English Electric

Co. Ltd. was entrusted with the contract for the supply, erection and commissioning of all the plant for the power house, viz., 19,200 b.h.p. vertical-shaft Kaplan turbines coupled to three 17,250 kVA, 11 kV umbrella-type alternators, intake hydraulic equipment, discharge regulators and 132 kV outdoor switching station.

High-Voltage Grid in Victoria, Australia

ANOTHER stage in the development of Victoria's new extra-high-voltage grid was marked by the opening recently of the State Electricity Commission's big new switching station at Rowville, just north of Dandenong. The new grid will operate at 220 kV, the highest voltage for bulk power transmission so far employed in Australia. The Rowville switching station will be a major junction for the transmission of electricity generated at the Latrobe Valley brown-coal power stations and the Kiewa and Eildon hydro-electric stations.

The S.E.C. has just completed a new 220 kV power line around the north-eastern perimeter of the metropolitan area from Rowville to Thomastown, which now provides interconnection between the new Yallourn and Kiewa transmission lines, already in operation, and is to erect a transmission line from Kiewa to Shepparton. From Shepparton the line will continue on to Bendigo. Eventually the whole of central Victoria will be encircled by 220 kV transmission lines continuing on from Bendigo via Ballarat and Geelong back to Melbourne.

Other main power lines are planned to run from Shepparton right along the Murray Valley to Mildura, and from Geelong to Camperdown, and possibly further on to Terang. The total length of this power grid when it is completed will be more than 1,000 miles.

The S.E.C. is also planning the transmission line which will carry Victoria's share of Snowy Mountains hydro-electric power. This line will operate at 330 kV and will link up with the Victorian grid at Dederang, between Albury and Kiewa.

Rapide Sans Nom Station

THE generating station at The Shawinigan Water and Power Company's new hydro-electric development at Rapide Sans Nom will be of the most modern outdoor type without any superstructure. It will operate under a head of 125 ft. and is designed for six generating units with a total capacity of 248 MW. Rapide Sans Nom is about 10 miles upstream from La Tuque. The outdoor type power plant will be the first of its kind on the St. Maurice. The Shawinigan Engineering Company Limited, wholly owned subsidiary of The Shawinigan Water and Power Company, is designing and will build the new plant.

The new dam at Sans Nom will raise the river level some 110 ft., a nine-mile diversion of the Canadian National Railways transcontinental main line will be necessary. Further, in order to obtain the full head of 125 ft. it will be necessary to dredge approximately 1,750,000 cu. yards of material from the bed of the river downstream from the Rapide Sans Nom site.

To carry power down the valley from the new site a transmission line will be built from Rapide Sans Nom to Trois-Rivières to operate at 230 kV. This will be the fourth line from Shawinigan's Upper St. Maurice River stations, and it will be tapped into the Company's recently constructed paralleling station at La Tuque to operate in conjunction with the three existing lines.

Target date for production of power from the first of the generating units at Rapide Sans Nom is November 1, 1958, and with all six in operation the total installed capacity of Shawinigan's seven power developments on the St. Maurice will be more than 1,500 MW.

Surface-laying a Cable

A NEW departure by the North of Scotland Hydro-Electric Board—laying cables overland instead of using pylons—has been welcomed by Inverness-shire Planning Committee, which recently gave its blessing to an application from the Board to lay an overland sheathed armoured cable from Invergarry generating station to the other works, some five or six miles to the west above the Falls of Garry. The cable will lie on top of the ground most of the way. Where it has to go underground it will be laid six inches deep, and where it crosses rivers it will be clipped to bridges.

Aluminium Limited Hydro Projects

A TWO HUNDRED and fifty million dollar programme for the proposed construction of a great new hydro-electric project on the Peribonka River in Northern Quebec to support a minimum of 150,000 tons of new aluminium smelting capacity in the Saguenay district of the province was announced by Nathanael V. Davis, President of Aluminium Limited, at the Annual Meeting of the Company's Shareholders in Montreal. Mr. Davis said that the Company's subsidiary, Aluminum Company of Canada Limited, was negotiating with the Government of the Province of Quebec for rights to develop 800,000 h.p. on the Upper Peribonka River about 80 air miles from Isle Maligne. First power would be generated by the new station in about three years provided a start on construction was made this summer.

The President said that assuming both the new Quebec expansion and the construction programme at Kitimat, British Columbia, are advanced without delay the Company's Canadian aluminium capacity will be increased from 650,000 tons at the end of 1955 to a figure in excess of one million tons at the end of 1959.

Describing the new power project Mr. Davis said " the power facilities would be constructed a few miles below the existing storage dam known as the Passe Dangereuse Dam which creates on the Upper Peribonka River one of our main storage reservoirs. An intake tunnel six miles long would be constructed from this reservoir to a point downstream where a gross head of 636 ft. can be developed and where an underground generating station will be installed.

" The estimated capital cost of the power development and the additional integrated smelter facilities including new facilities for the production of alumina is expected to be of the order of $250,000,000 based on current price levels. Of this amount approximately $135,000,000 would be required for the power development alone. Mr. Davis said that Aluminium

Limited continued to have an active interest in other hydro-electric developments, not only in Canada but also in the Gold Coast and in French West Africa where power sites are adjacent to bauxite resources.

Electricity for Mityana

THE Uganda Electricity Board has announced that Mityana is to be supplied with electricity. This constitutes the next stage in the Board's programme for the distribution of electricity in Uganda which will make supplies of electricity available initially to nearly 500 premises. A 33 kV line is to be erected westwards from Kampala to Mityana and then southwards to join up with the existing Kampala-Masaka line, some 35 miles south-west of Kampala, to form a ring main. Over 100 miles of line will be constructed, including several spur lines to serve places off the route of the main lines.

In addition to the township of Mityana, supplies of electricity will be made available to Bulopa, Bukojo, Jeza, Mwera, Kirwi, Budo, Ndodo, Tondola, Kibibi, Kabasanda, Bukandala, and other places. Coffee factories and hulleries, tea factories, ginneries, maize mills, oil mills and saw mills will all benefit by the scheme. Provision is also to be made for connecting up hospitals and Saza and Gombolola headquarters at several places.

The Board recently approved another scheme in Buganda, being an extension northwards from their Kampala-Bombo line, comprising 35 miles of electric line, to give supplies to some 200 consumers including cotton ginneries, oil mills, the Bukalasa Agricultural Station and Saza and Gombolola headquarters. The villages of Kalule, Bowa, Wobulenzi, Luwube and Luwero will benefit by the supply.

The capital cost of these two distribution schemes, which will take about five years to complete after construction starts, is estimated at nearly £350,000. Premises, however, will be connected as far as possible as the electric lines are erected. The main electric lines are of sufficient capacity to deal with the electricity requirements of many more than the 700 consumers expected to be supplied from the two schemes in the first few years.

Sir Adam Beck No. 2

WHILE this issue is in the press Dr. Richard L. Hearn, Chairman of Ontario Hydro, will give the Annual Lecture to the Supply Section of the Institution of Electrical Engineers, in London, on the Sir Adam Beck No. 2 station, Niagara Falls. This station —one of Ontario Hydro's outstanding achievements— will have an ultimate installed capacity of 1,370 MW in 16 units, in addition to which there will be a pumped-storage scheme incorporating six 47,000 h.p. reversible pump-turbines and 15,000 acre-ft. of storage at 85 ft. head. The station was officially opened by H.R.H. the Duchess of Kent on August 30, 1954, when three units were in operation. Four more units followed later in the year, and five in 1955. The pumped-storage stage is now under construction and is scheduled for completion next year. The four remaining generating units will be installed when required. Generation is at 60 cycles, which has superseded the 25-cycle system.

Correspondence

That Longest Water Tunnel

To the Editor of WATER POWER

On pages 89-90 of the March issue of WATER POWER it is stated that the Vinstra tunnel, 23,700 m. long, "is claimed to be the longest water tunnel in Europe, if not in the world." According to the Editor's Note: "This is true only if the penstock and tailrace tunnel are taken into account." And further on: "the length of this tunnel is exceeded by that of the Loch Treig-Lochaber tunnel serving the Lochaber works of the North British Aluminium Co. Ltd.," which means that the latter tunnel is the longest in Europe.

May I take the liberty of pointing out that in the Piave-Boite-Maé-Vajont Plant, North Italy, the section of the main supply tunnel from the Pieve Reservoir to that of Val Gallina is 24,600 m. (80,708 ft.) in length. This section is followed by another one of about 2,500 m. long, which connects the Val Gallina reservoir with the power station of Soverzene (operating since January 1951). The main supply tunnel, in its turn, is preceded upstream by the supply tunnel from the Boite, about 5,000 m. long, and is connected with the tunnel conveying the water of the Maé, which runs into the main supply tunnel, consisting of a first section of about 8,500 m. and a second section of approximately 2,500 m. in length. Even if we do not take into account the connected tunnels and penstocks, I think that the Soverzene tunnel is longer than the above mentioned ones.

May I add, however, that the most important element to be considered when the length of a tunnel is under discussion is the length between two adits, and not the total length.

ING. CARLO SEMENZA.
Director, Società Adriatica di Elettricità.

High-Head Sluice Gates

To the Editor of WATER POWER

Please refer to your issue dated February 1956. The article on high-head sluice gates by Mr. Ernst Haase, page 55, contains erroneous information on the hollow-jet valve. I have been engaged in the design of hydraulic equipment for the Bureau of Reclamation for the past thirty years, and am the inventor and joint patentee of the hollow-jet valve which was mentioned in the concluding remarks of Mr. Haase's article.

The article states that hollow-jet valves were no longer used for regulating purposes within a conduit. It would be appreciated if you will correct this statement in your publication to the effect that hollow-jet valves have never been used in closed conduits.

The hollow-jet valve should only be placed at the downstream end of an outlet pipe where the jet may discharge freely into the atmosphere. However, it may be operated satisfactorily when partially submerged with the water not higher than the centreline of the valve. It is used primarily for regulating purposes and will not cavitate or vibrate at any opening.

B. H. STAATS.
Supervisory Engineer, U.S. Bureau of Reclamation.

Fig. 1. General view of the site, showing Persenbeug Castle on the left

The Ybbs-Persenbeug Plant

Dr. E. Königshofer, of Österreichische Elektrizitätswirtschafts A.G., describes a 270 MVA run-of-river station which Österreichische Donaukraftwerke A.G. is constructing on the Austrian Danube and is expected to form one of a chain of stations between the Austrian-Bavarian border and Vienna

EFFORTS to utilise the Austrian Danube for power supply were made as long ago as in the time of the former Austro-Hungarian monarchy which was disrupted at the end of World War I. Notwithstanding this it is only within the last few years that the amount of energy obtainable by harnessing the river was reliably established. Not until the electricity industry was nationalised in 1947 were steps initiated to elaborate an overall development plan for the Austrian Danube. To be sure, the relative data had been collected before, but no co-ordinated use had been made of them. Fig. 2 shows the course of the Austrian section of the Danube, and indicates the stages envisaged under the overall plan. Over a length of 343 km. a net head of about 130 m. is divided into 14 stages, the envisaged utilisable water flow amounting to 1,750 cu. m. per sec. at the topmost and to 2,300 cu. m. per sec. at the lowest stage. The installation of generating units with a capacity of 2,129,000 kW is planned by which 14 billion (14×10^9) kWh may be produced annually.

Of those 14 stages one has been developed, this being the topmost stage, at Jochenstein, on that section of the Danube where it forms the border between Austria and Bavaria. A preliminary description of Jochenstein was given by the present author on page 275 of the July, 1954, issue of WATER POWER.

During the first World War a plan was conceived to erect a power plant at Wallsee, and was approved by the authorities in 1919 but never realised.

In 1922 a Swiss engineer by the name of Höhn began to draft a new project. As the site for the plant the narrow passage of the Danube near the castle of Persenbeug on the left river bank (on the right side there is the village of Ybbs) was envisaged (see Fig. 3). In 1924 he submitted to the authorities a fully elaborated project for which the licence was granted in 1932. The project, however, was not carried out.

Since that time the plan of erecting a power plant at Ybbs-Persenbeug was again and again revived, and the Höhn project was repeatedly revised and adapted to the latest technical developments in hydro-electric plant construction. During the last years of the first Austrian Republic, which ceased to exist in 1938, there was a serious business depression in the country and thus erection of a Danube power plant could not be entertained. When in 1938 the German Reich began to determine the destinies of Austria the Rhein-Main-Donau Aktiengesellschaft was entrusted with the task

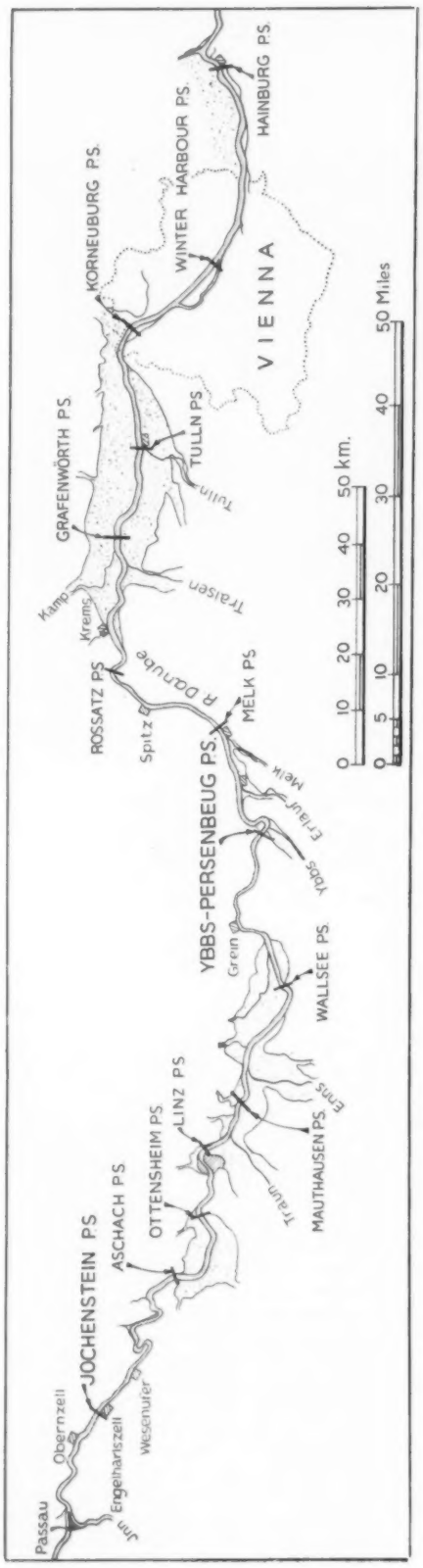


Fig. 2. Map of the Austrian Danube showing the locations of Jochenstein, Ybbs-Persenbeug and the twelve projected power stations

of building a power plant at Ybbs-Persenbeug. Bridges, railway tracks and roads were built for connecting the power site with the existing railway lines and roads, and a cableway for the transport of building materials across the Danube was erected as well as a concrete-mixing plant. In principle the Höhn project was retained providing for the installation of 10 Kaplan turbines each of 14,500 h.p. and a power production of 800 million kWh per year; the maximum water level was to amount to 224·13 m. and the backwater area to be 24 km. long.

In 1940 Arno Fischer, who advocated the erection of a submerged plant, took over the management of the Rhein-Main-Donau A.G. and in spite of serious warnings wished to execute the project in this manner. He altered the original plan to cover the installation of 16 turbines each of 14,000 h.p. and the raising of the maximum water level to 225·63 m., as a result of which power production was to increase to one billion kWh and the length of the back water area to 30 km. Although the project was not licensed by the authorities far-reaching preparations were made for its execution. The pit for the locks on the left river bank as well as the pit for the power house on the right river bank were cofferdammed. As a result of the war, building operations were discontinued in 1944 and all building facilities, workers' barracks, etc., laid idle.

The foregoing projects for the development of a Danube stage at Ybbs-Persenbeug had one great fault: they determined the size of the stage to be developed without taking heed of the requirements for a full-scale utilisation of the Danube by further stages. This was recognised, but for the time being was not further considered.

When in 1945 the second Austrian Republic came into being the power site was declared "German property." The Austrian Government was unable to proceed with the construction of the plant and had to be satisfied with preserving the building site in good condition. This task was entrusted to Dr. Grzywienski, subsequently to be appointed Professor at the Vienna Institute of Technology, who elaborated a new project.

Expert circles in Austria, however, came to realise more and more that the Ybbs-Persenbeug project should not be dealt with independently but had to be fitted into the overall schemes for a comprehensive utilisation of the Danube for power production. A "Danube Committee" presided over by Oskar Vas was entrusted with their co-ordination.

The year 1947 marks a turning point in the Austrian electricity industry, which was nationalised pursuant to the Second Nationalisation Law of March, 1947, which provided also for the establishment of the Österreichische Donaukraftwerke Aktiengesellschaft. In the same year the contract concluded with Dr. Grzywiensky expired and was not renewed. The new

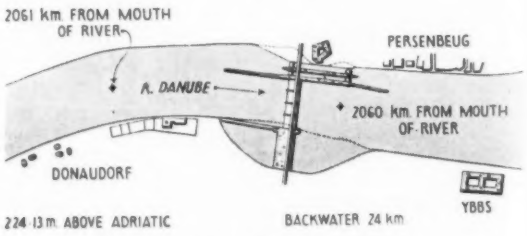


Fig. 3. Sketch of Höhn's project

Fig. 4. General view of work on right bank of river, November 29, 1955

company elaborated a new project the characteristic features of which were as follows: The plant axis was to be oblique to the lock axis; the power house would be divided into two so that one-third of the capacity adjoined the southern wall of the lock whereas the other two-thirds were located in the bight of the power site on the right bank of the river. Under this project the envisaged power production was to amount to one billion (1×10^9) kWh per annum. The overall plan, mentioned above, for the Austrian section of the Danube has been elaborated by this company.

On July 17, 1953, the Soviet element declared its readiness to surrender the power site and to put it at the free disposal of the Austrian Government, and the way was laid open for realising the Danube power plant. For the Österreichische Donaukraftwerke A.G. a new managing board was appointed, the members of which were chosen among the managing board of the Tauernkraftwerke A.G., and the engineer Böhmer and Mr. Mosbauer are making available to the new company their valuable experience in power-plant construction gained at Kaprun. To harmonise with the Danube overall scheme the Ybbs-Persenbeug project was once more altered, the envisaged maximum water level being raised to 226·20 m., resulting in an increase of power production to 1,300 million kWh.

Final drafting of the project was completed in December, 1953. In January, 1954, procedures and details of the invitation to bid in respect of the generating station, weir and lock were advertised. In September the first orders were placed and on October 1, construction work started.

Technical Data

On the basis of many years' measurements it has been ascertained that on 100 days per annum a utilisable waterflow of about 2,150 cu. m. per sec., on 200 days of about 1,500 cu. m. per sec. and on 300 days of about 1,050 cu. m. per sec. will be available. It has been decided to base the project on an expected waterflow of 2,100 cu. m. per sec. during 105 days in the year. This waterflow will be utilised by six equal turbines which consequently have been designed for 350 cu. m. per sec. each. At a net head of 10·6 m. each turbine on full load and estimated efficiency will have a capacity of 43,900 h.p. or 32,300 kW at 68·2 r.p.m. The generators will be direct coupled and will have a nominal output of 45,000 kVA each, the power factor being 0·8 and their rated voltage 10·3 kV + 8% − 5%. Their total weight will amount to about 405 tons each. They are expected to yield an annual power production of 1,274 million kWh—550 million kWh in the winter and 724 million kWh in the summer.

Figs. 6 and 7 show the general layout of the project under development, Fig. 11 is a power-house cross section, and Fig. 13 is a picture of an architectural model of the scheme. A view of the stretch of river concerned appears in our titleblock, Fig. 1. Some details may now be given of the structures to be erected.

The twin locks lie close to the left river bank, each having a usable width of 24 m. and a usable length of 230 m. with adjoining outer basins upstream and downstream. The separating central wall is 10·5 m. thick. For the upper end mitre gates are envisaged, and for the lower end vertical-lift gates. The drives for the vertical-lift gates will be located on the three pillars of the lock walls whereas those for the mitre gates will be sunk in the crests of the lock walls. The gates will be operated from a control-point at the lower end. Filling and emptying of the chambers will be effected by the gates themselves. For filling one lock chamber 60,000 to 80,000 cu. m. of water will

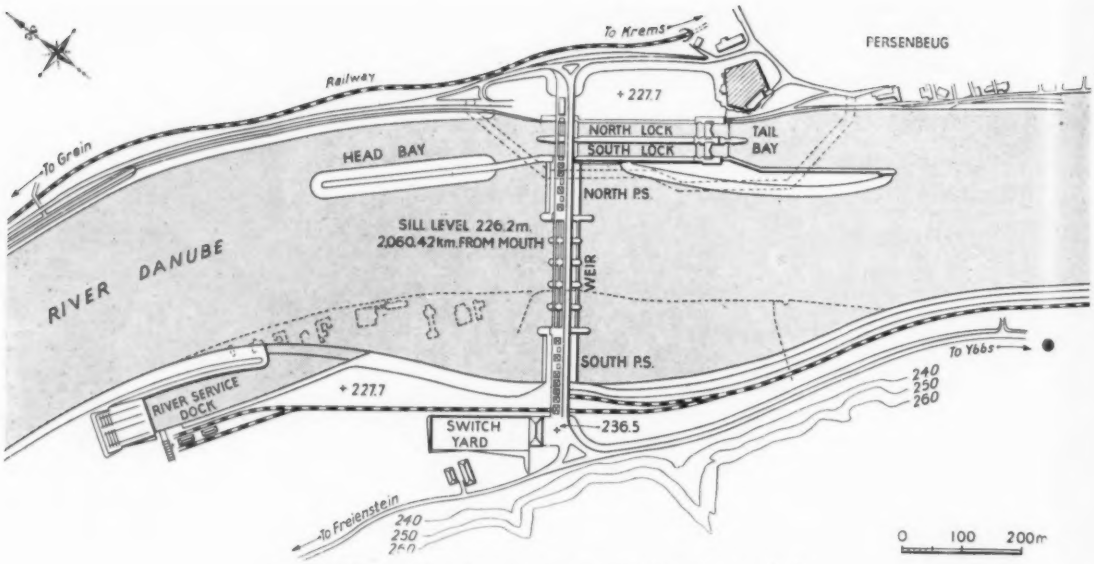


Fig. 5. Plan of development as now being constructed

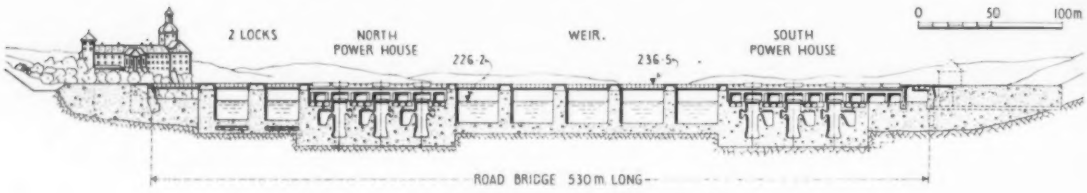


Fig. 6. Sectional elevation taken from bank to bank

Fig. 7. Progress of work on locks to September 20, 1955

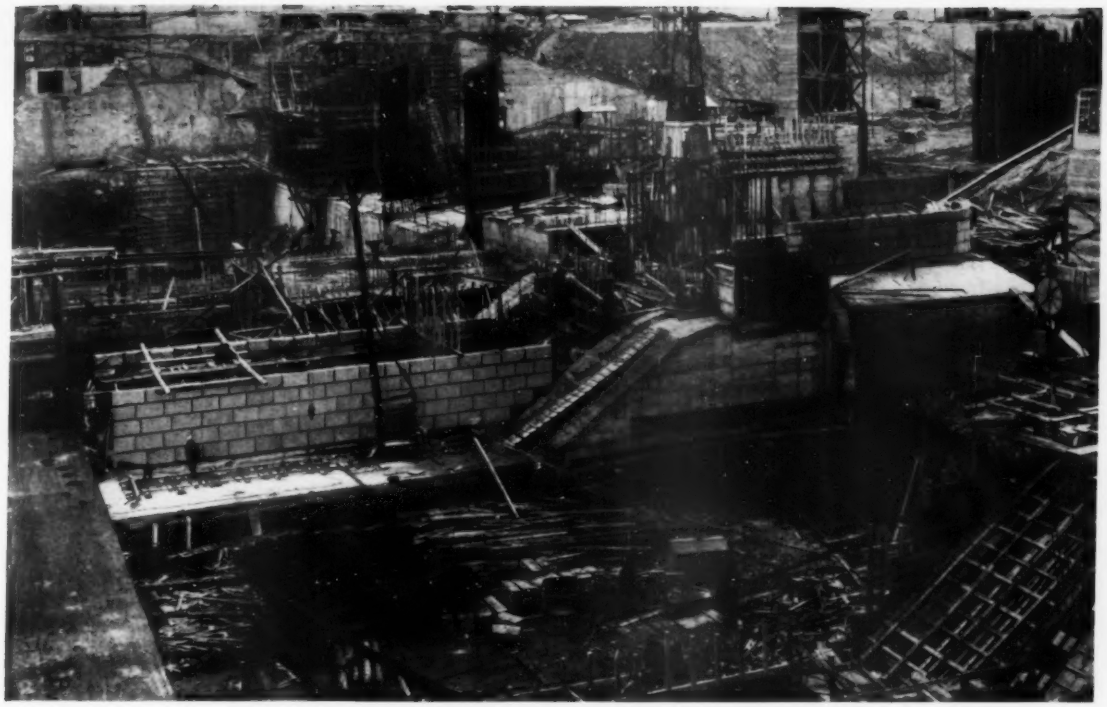


Fig. 8. Weir and intake structures as at October 24, 1955

be required. The outer basins will have a width up to 100 m. Each of the two lock chambers can be closed against the head water and tailwater through stoplogs and thus be drained. After all weir spillways have been opened, the two locks will be used in the case of flood flows for draining off exceptional run-offs. The hydraulic efficiency of the locks has been proved by model tests.

As mentioned before, the power house has been divided into a northern and a southern part. The northern part will adjoin the lock, whereas the southern part will be located in a cove on the right river bank, the weir being between the two sections. The roofs of the power houses will serve as crane runways and as road bridges. The transformers adjoining the individual generators will step up the electricity generated to 225 kV and will be connected to the open-air switchyard on the right bank by single-phase oil-filled cables laid in the gangways under the road-bridge runway. In the roofs of the power houses there will be hatches for mounting and assembling the generating units. For the interior of each part of the power house a 20 ton travelling crane will be provided.

The scrollcases of the turbines can be closed against the headwater by stoplogs and will be completed and mounted by means of a universal crane. It will also be possible to seal the turbine inlets by stoplogs which may be let down along the pier noses in front of the trashracks. The turbine draft tubes may also be sealed against the tailwater.

Separating piers, 15·5 m. wide, will be interposed between the power-house sections and the weir, and in these piers two auxiliary turbines each of 2,400 h.p. will be installed to cover the requirements of their respective power-house sections. A standby diesel generating set will also be provided.

The weir will consist of five waterways with a free width of 30 m. each. The four weir piers will each be 7·5 m. thick. Hook-shaped double sluice gates of a height of 13·5 m. will be used, the drives being mounted in the weir piers. Each sluice gate can be closed by means of stoplogs against the headwater and the tailwater and thus be drained.

Model tests have also been used as a basis for the design of the weir.

Two crane bridges and one road bridge will connect the two river banks. The steel bridge within the zone of the weir and the locks will be equipped with a 6 m. wide concrete track and bicycle roads. In the zones of the power houses the tracks will rest on the steel concrete supports.

The crane bridges will serve as runways for two universal cranes, each having a carrying capacity of 136 tons and a gauge of 16 m.

An assembling bay, workshops and storing rooms will be built on the right river bank where also the control building with the switch tower for remote control and supervision of the power houses and weir will be erected.

The open-air switchyard will have a size of 70 × 180 m. Three 220 kV overhead lines will lead off to a substation of the Verbundgesellschaft.

A normal-gauge siding on the right river bank will connect the plant with the Austrian Federal Railroad system.

The Kaplan turbines will operate under a net head varying between 6 m. and 14 m. At a net head of 12·45 m. and a waterflow of 310 cu. m. per sec. their maximum capacity may be assessed at 34,400 kW. The turbines will be among the largest at present in

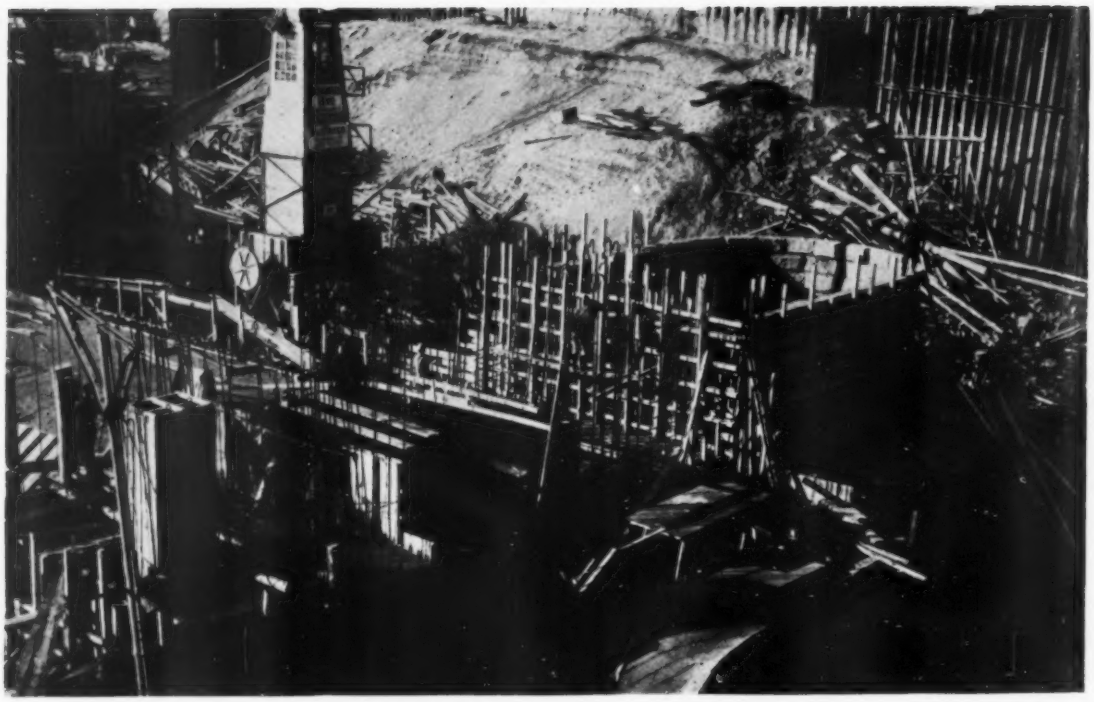


Fig. 9. No. 2 weir pillar under construction, November 29, 1955

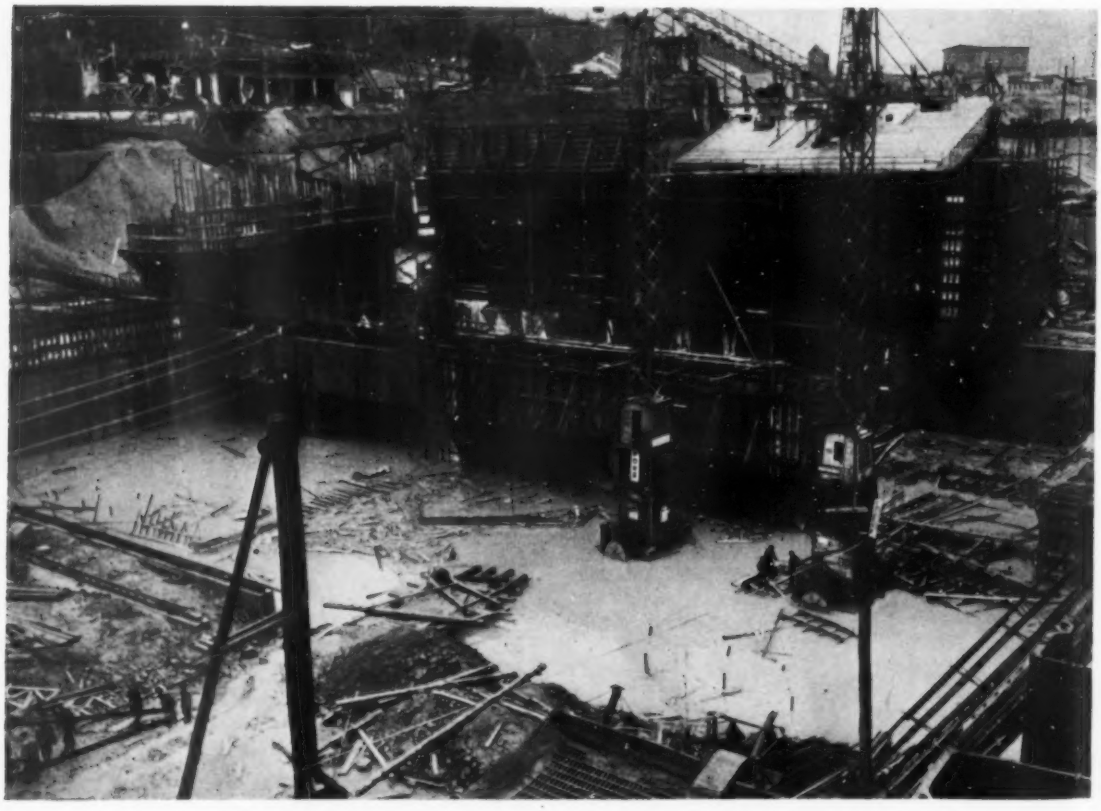


Fig. 10. South power house under construction, March 4, 1956

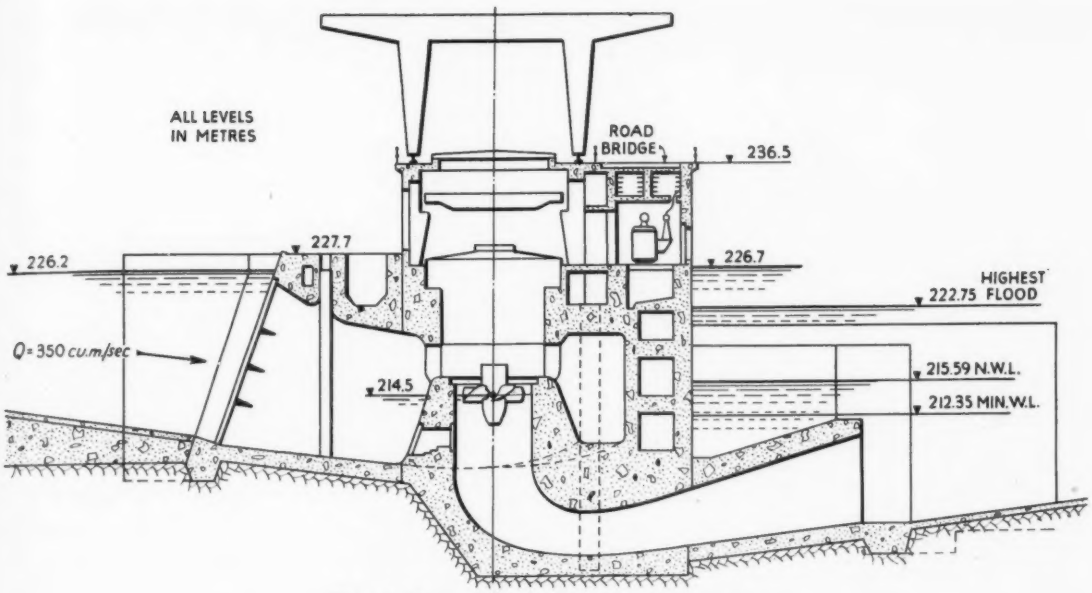


Fig. 11. Cross section through power house

use in Europe, having a wheel diameter of 7·4 m., a net weight of 754 tons, and a gross weight, including all accessories, of about 942 tons. The desired capacity and frequency control will be achieved by means of an electro-hydraulic regulator. Load distribution will be effected automatically in order to obtain an optimum overall efficiency. Under the type of control envisaged not only capacity and frequency in relation to the network but also the ratio MW:Hertz, expressing the capacity change by which the plant counteracts a frequency change of one Hertz, may be chosen.

The auxiliary turbines will, likewise, be of the Kaplan type.

The waste heat of the generating units will be used for heating the engine rooms.

The generators, which will be of ELIN manufacture, will have a special excitation arrangement designed to avoid the disadvantages, in the case of low-speed vertical-shaft alternators, of the usual method of mounting the main and pilot exciters above the generator. This increases the necessary height of the power house, or alternatively complicates the weather-proof structure, and it is sometimes difficult to allow sufficient airgap in the exciters to allow for the flexure of the shaft, especially in the case of umbrella-type machines without an upper guide bearing.

Excitation will therefore be derived from a 700 kW high-speed motor-generator set consisting of a three-phase 380 V motor driving a main and a pilot exciter. To render the arrangement self-contained the motor is supplied from a flat three-phase low-voltage auxiliary alternator mounted above the magnet wheel of the main generator, this alternator also supplying the essential auxiliaries for the unit.

Construction Work and Facilities

The building-site equipment had to be adapted to the existing requirements such as the quantity of concrete to be poured, the earth to be removed, etc., as well as to local conditions. Altogether 550,000 cu. m. of concrete will have to be poured for the locks, weir and power house and about 900,000 cu. m. of gravel will be required. A total quantity of 1·8 million cu. m. of material will have to be moved, 250,000 cu. m. being rock; the right bank of the Danube at this point consists of gravel and sand. Facilities and equipment for the building site include, therefore, an aggregate-preparation plant, two concrete-mixing plants each for 90 cu. m. per hour of concrete, an aggregate cableway, cranes, among them one floating crane of a carrying capacity of 200 tons, compressor plants, pumping installations, rotary tower cranes, and conveyors in the excavations. For handling spoil trackless transport is being used exclusively. Two ferries are available, so that the construction of a building bridge across the Danube did not appear necessary.

At the time when construction work was begun in October, 1954, the following enclosures were available: on the left bank the cofferdam for the locks, on the right bank a simple sheet piling which follows approximately the old course of the river bank.

The 33 km. long backwater basin requires extensive reconstruction. On both river banks the areas used for agricultural production will be raised one metre above the marginal water level, existing roads on both river banks will have to be raised, and bridges rebuilt as well as river beds regulated. The slopes of the banks will have to be reinforced by means of rubble fill and stone pitching, about 150 houses will have to be rebuilt or newly erected. On the other hand, from the increased storage, navigation will derive various advantages.

The following timing schedule is to be observed:

Clearing of weir waterways 1 and 2 ..	spring 1956
Completion of construction of southern part of power house	summer 1956
Navigation through southern lock ..	end 1956
Navigation through northern lock ..	beginning 1957
Clearing of weir waterways 3 and 4 ..	beginning 1957
Partial storage (southern part of power house put into operation)	spring 1957
Full storage (northern part of the power house put into operation) ..	beginning 1959

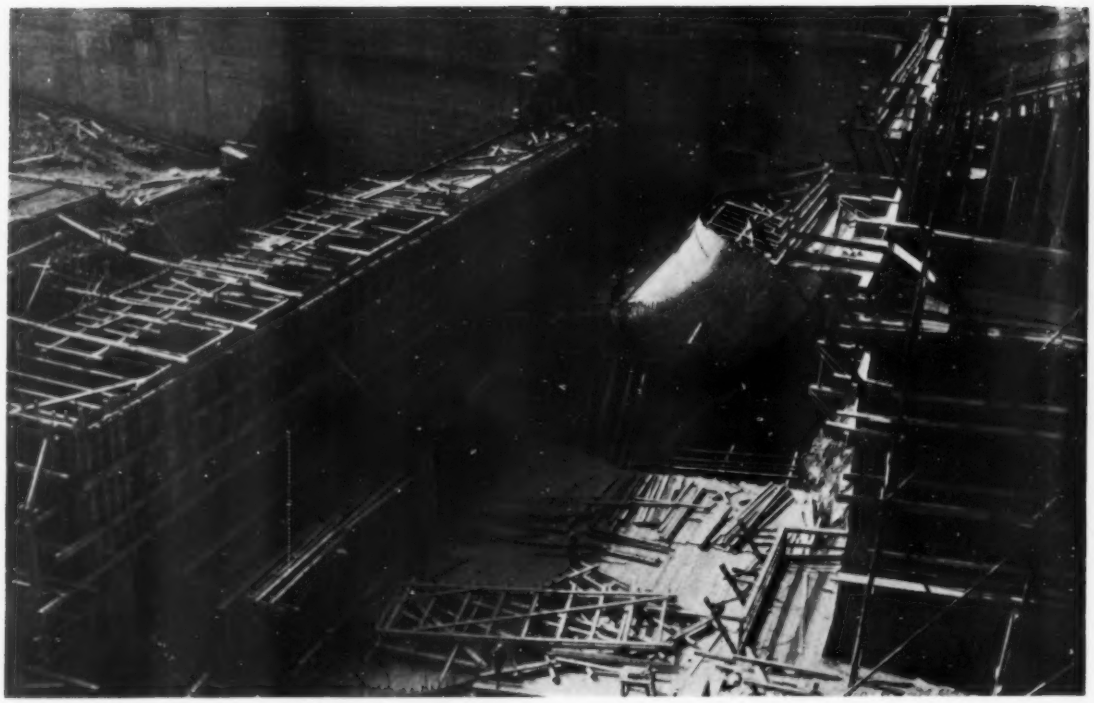


Fig. 12. Outlet structure and draft tube, March 21, 1956

Although on account of the floods occurring in July, 1955, both excavations were inundated and thus observance of the timing schedule for 1955 was endangered, building operations had made favourable progress until September, 1955, and by that time 20 per cent. of the entire quantity of concrete had already been poured.

Architectural Design

In order to find a satisfactory solution for the architectural execution of the generating station, power house, lock and the control building a competition was arranged. The first prize was awarded to architect Karl Hauschka whose draft project will be carried out (Fig. 13). But the storage area also gives rise to various problems which cannot be solved without the architectural expert; new buildings have to be erected, aprons made for the river banks, land raised and roads executed whereby the power site will take on a new appearance. To develop the site in such a way that it will fit harmoniously into the general character of the landscape is the aim of the constructors of the Ybbs-Persenbeug power plant, the Österreichische Donaukraftwerke Aktiengesellschaft, whose headquarters are in Vienna.

Construction Costs of the Project

Total costs are given at AS 2,300 million, giving a cost price of AS 9,200 per horsepower and a power price of AS 1·77 per kWh produced annually.

In this connection the following statement deserves special interest: Although since the drafting of the first

Project Year	1928	1938	1940	1946	1953
Maximum water level ...	224·13	224·13	225·63	225·63	226·20
Length of backwater area	24	24	30	30	33
Number of generating units	10	8	16	6	6
Utilisable waterflow in cu. m./sec.	1800	1800	1936	2000	2100
Capacity of turbines in h.p.	145.000	160.000	224.000	210.000	250.000
Power production in million kWh	800	800	1.000	1.000	1.300
Estimated costs (price basis 1955) in million AS	1.900	—	2.420	2.090	2.300
Costs per h.p. in AS ...	13.100	—	10.800	9.900	9.200
Costs per kWh in AS ...	2·38	—	2·42	2·09	1·77
Building time in months	72	—	60	96	50

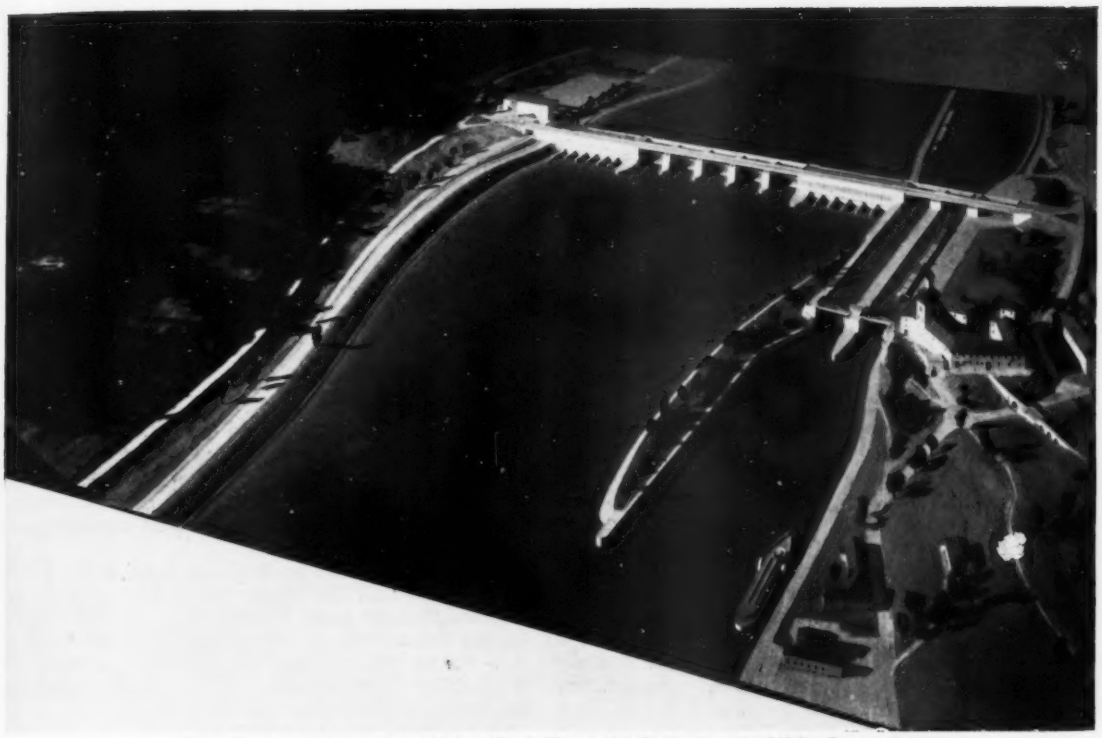


Fig. 13. Architectural model of Karl Hauschka's design for Ybbs-Persenbeug

project by the Swiss engineer Höhn in 1928 almost 30 years have elapsed, during which Austria has experienced numerous price increases the price per kW has declined as is shown by the table on page 214.

This progress is to be attributed to the higher efficiency of the machines to be installed as well as to the improved working methods resulting from the application of more efficient machinery. The application of improved machinery has the further effect that compared to the 1928 project the building period under the 1953 project has been reduced to two-thirds in spite of an increase of power production by more than 50 per cent.

NOTE: This article has been specially written for WATER POWER, but in its preparation the author has obtained valuable information from the September, 1955, issue of ÖZE (Österreichische Zeitschrift für Elektrizitätswirtschaft) which discussed the development from many different aspects.

Engineers and Contractors

Apart from the executives already indicated there are the following engineers of the Österreichische Donaukraftwerke A.G. to be mentioned who are engaged in designing and constucting the hydro-electric plant:—

F. Makovec: overall planning and construction.
F. Susan: mechanical and electrical plant.
W. Roehle: general and hydraulic steel structures.
R. Oktabec: storage facilities.
R. Fenz: superintendent of weir construction.
A. Niessner: superintendent of storage construction work.
H. Schneider: general and landscape architect.
F. Uhl: materials testing.

The following firms are engaged in construction or in the manufacture and supply of plant and equipment:—

Civil-Engineering and Building Work
Hr. Rella & Co., Vienna.
Ed. Ast & Co., Vienna.
Mayreder, Kraus & Co., Vienna.
STUAG, Vienna.
Union-Baugesellschaft, Vienna.
"Universale" Hoch-und Tiefbau A.G., Vienna.
Wiener Hoch- und Tiefbau G.m.b.H., Vienna.

Bridges, Weir and Lock Gates, Cranes, Ice Aprons and other Steel Structures
VÖEST, Linz.
Waagner-Biro A.G., Vienna and Graz.
Wiener Brückenbau A.G., Vienna.
Dortmunder Union, Dortmund.
Krupp, Rheinhausen.
MAN Maschinenfabrik, Augsburg-Nürnberg.
Schiffswerft, Korneuburg.
Schiffswerft, Linz.

Mechanical and Electrical Equipment
J. M. Voith, Heidenheim (Brenz).
J. M. Voith, St. Pölten.
Escher Wyss, Zürich.
Masch. Fabrik Andritz, Graz-Andritz.
ELIN A.G., Vienna.
Ansaldo-San Giorgio, Genoa.
VÖEST, Linz.

Calculating Flow through Turbines

Sigfrid Andersson presents an analytical method for calculating the volume of water passing through the turbines at a power station and a statistical investigation of the degree of accuracy obtainable when drawing and planimetring curves used in conjunction with his method

PART ONE

IN this article, only the so-called point method of using hydraulic current meters will be considered, as this is the method most often practised in Europe, and is probably more accurate than other known methods which might be used in similar conditions.

It is assumed that measurement is made in a rectangular opening, but measurement can also be made in a circular opening or area, as in the case of a penstock, when a rod carrying the current meters is turned round the centre at a constant rate. Actually when used in a penstock the method is mathematically correct, whereas this is not so when it is used in a rectangular opening, for in the latter case the current meters cannot run right up against either the upper or lower edge of the opening. A relatively simple analytical expression can also be obtained for both point and integration measurement when the method is used in a penstock. This will be treated in a future article. The author also assumes that the reader is acquainted with the actual measuring procedure and thus only the method of treating the results will be given here.

The method probably most used when the aim is to get the greatest possible accuracy in calculating the measured values, is to obtain the velocity vectors v_1, v_2, v_3 ..... from the current-meter calibration curves or tables made from the curves. The velocity vectors are then joined by curves and by planimetring the surface below the horizontal curves an average velocity vector can be determined for each curve, from which the resulting curve of vertical vectors can be obtained. In the same way a new average velocity vector v_M applicable to the whole measuring area may be determined. This method of calculation obviously involves much tiring work, especially when it is considered that the determination of the efficiency and combination curves for a Kaplan turbine takes about 30 tests, each one involving 50 to 150 measurements. To avoid this work it would seem reasonable to design a counting apparatus capable of recording the water flow Q direct. The question is, could such an instrument be manufactured at a reasonable price, and would it be a suitable instrument for the field? A disadvantage of such an instrument is that it must have a counter and chronograph—or possibly only a chronograph for each current meter—in order to be able to ensure that the meter is not giving faulty readings due to swirls, contact faults, etc. However, the work can be considerably simplified by means of a counting diagram which can be drawn beforehand, so that the time to determine Q can be limited to approximately 1/20 of the time required to draw the curves and planimeter them. Such a counting diagram, although not completed, may be found in "Normen für Wassermessungen aufgestellt vom Schweizerischen Ingenieur und Architekten-Verein, 1924."

Only the rectangle method has been used in this work. As a result, the value of water volume obtained in practice is too great, because most velocity profiles (with a few exceptions) are convex in the direction of flow unless specially designed measuring nozzles are used. "Der Genauigkeitsgrad von Flügelmessungen bei Wasserkraftanlagen vom Prof. Dr. Ing. A. Staus, 1926," mentions that numerical calculation using the Tschebyscheff integration formula has been used by American manufacturers. Dr. Staus states, however, that he is unacquainted with the degree of accuracy obtained when compared with other analytical or planimetring methods; furthermore, the division of the current meters as laid down by this formula is particularly inappropriate, especially for $m = 6$ current meters (nor can it be used for $m = 8$). The use of a counting diagram also has the advantage that by numerical control one can quickly ascertain the correctness of the estimated result. Thus there is no need for tiresome and possibly incorrect tabulation which is often the consequence when replanimetrations have been made for the sake of numerical control. It is also a great advantage to be able to fix the turbine efficiency as exactly as possible while the equipment and the personnel are still available on the test site, for if any retesting work should be required, it can be done immediately.

In the preparation of this counting diagram, the chord trapezium method has been principally used; it has been corrected by two-thirds of the difference between the tangent and the chord trapezium. The adjustment of two-thirds has been arrived at from experience. Latterly Professor C. G. H. Esseen of The Royal Institute of Technology in Stockholm has drawn the writer's attention to the fact that this coefficient is the best that can be used and that the formula is now the same as the Euler-Maclaurin formula, with only the first correction term (see "The Calculus of Observations" by Sir Edmund Whittaker and G. Robinson, Blackie & Son Limited, London and Glasgow, page 135). The areas adjacent to the walls, i.e., from points 2 and 7 to the wall, have been included below a parabolic curve by extrapolating the curve to the wall.

A deduction from the formula may be made as follows:

If m = number of current meters
and p = number of horizontals
then $F + F_1 + F_8 = v_m (m - 3) x + 1{\cdot}8 x =$
$= (m - 1{\cdot}2) x v_m$ ...(1)

$$F_{chord} = x (0{\cdot}5 v_2 + v_3 + v_4 + v_5 + v_6 + 0{\cdot}5 v_7) \quad ...(2)$$

$$F_{tangent} = x (v_3 + v_4 + v_5 + v_6) + 0{\cdot}5 x (v_2 + v_7) + \frac{0{\cdot}5^2 x^2}{2} (\tan \alpha_2 + \tan \alpha_7) \quad ...(3)$$

A parabola $v = a + bX + cX^2$ is laid through v_1, v_2 and v_3; from which α_1 and F_1 can then be estimated as follows:—

For $X = 0$ we obtain $v_1 = a$ ...(4)

„ $X = 0{\cdot}6 x$ „ „ $v_2 = a + b\,0{\cdot}6 x + c\,0{\cdot}36 x^2$ ...(5)

„ $X = 1{\cdot}6 x$ „ „ $v_3 = a + b\,1{\cdot}6 x + c\,2{\cdot}56 x^2$ ...(6)

From these equations b and c are calculated as follows:—

$$b = \frac{-55 v_1 + 64 v_2 - 9 v_3}{24 x} \quad ...(7)$$

$$c = \frac{5 v_1 - 8 v_2 + 3 v_3}{4{\cdot}8 x^2} \quad ...(8)$$

$$\frac{dv}{dX} = b + 2cX$$

For $X = 0{\cdot}6 x$ is obtained

$$\frac{dv}{dX} = b + 2c\,0{\cdot}6 x = \tan \alpha_2$$

$$\tan \alpha_2 = \frac{-55 v_1 + 64 v_2 - 9 v_3}{24 x} + 1{\cdot}2 \frac{5 v_1 - 8 v_2 + 3 v_3}{4{\cdot}8 x}$$

$$\tan \alpha_2 = \frac{1}{24 x} (-25 v_1 + 16 v_2 + 9 v_3) \quad ...(9)$$

Similarly $\tan \alpha_7$ is obtained by changing the indices 1, 2 and 3 for 8, 7 and 6 respectively.

$$\tan \alpha_7 = \frac{1}{24 x} (-25 v_8 + 16 v_7 + 9 v_6) \quad ...(10)$$

$$\therefore F_{tangent} = x (0{\cdot}5 v_2 + v_3 + v_4 + v_5 + v_6 + 0{\cdot}5 v_7) + \frac{0{\cdot}25 x}{48} (-25 v_1 + 16 v_2 + 9 v_3 + 9 v_6 + 16 v_7 - 25 v_8)$$

$$\therefore F_{tangent} = \frac{x}{192} (-25 v_1 + 112 v_2 + 201 v_3 + 192 v_4 + 192 v_5 + 201 v_6 + 112 v_7 - 25 v_8) \quad ...(11)$$

The term for F_{chord} is extended by 192 in order to get the same denominator as for $F_{tangent}$.

$$\therefore F_{chord} = \frac{x}{192} (96 v_2 + 192 v_3 + 192 v_4 + 192 v_5 + 192 v_6 + 96 v_7) \quad ...(12)$$

The correction for F_{chord} is now obtained from the following:—

$$\Delta F = \frac{2}{3} (F_{tangent} - F_{chord})$$

$$\Delta F = \frac{x}{192} (-16{\cdot}66666 v_1 + 10{\cdot}66666 v_2 + 6 v_3 + 6 v_6 + 10{\cdot}66666 v_7 - 16{\cdot}66666 v_8)$$

$$F = F_{chord} + \Delta F = \frac{x}{192} (-16{\cdot}66666 v_1 + 106{\cdot}66666 v_2 + 198 v_3 + 192 v_4 + 192 v_5 + 198 v_6 + 106{\cdot}66666 v_7 - 16{\cdot}66666 v_8) \quad ...(13)$$

The areas F_1 and F_8 are limited by the parabola previously drawn and are obtained by means of integration

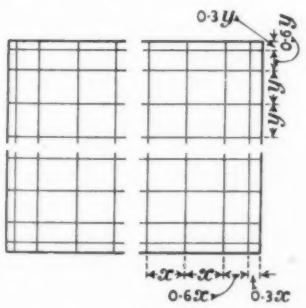
$$F_1 = \int_{-0{\cdot}3 x}^{0{\cdot}6 x} (a + bX + cX^2)\, dX$$

TABLE I—BASIC DIAGRAM FOR WATER VOLUME MEASUREMENT

$$Q = \frac{A}{(m - 1{\cdot}2)(p - 1{\cdot}2)} \Big[$$

+0·346	+0·459	+0·607	+0·588 +	+0·588	+0·607	+0·459	+0·346
+0·459	+0·609	+0·805	+0·781 +	+0·781	+0·805	+0·609	+0·459
+0·607	+0·805	+1·063	+1·031 +	+1·031	+1·063	+0·805	+0·607
+0·588	+0·781	+1·031	+1·000 +	+1·000	+1·031	+0·781	+0·588
+0·588	+0·781	+1·031	+1·000 +	+1·000	+1·031	+0·781	+0·588
+0·607	+0·805	+1·063	+1·031 +	+1·031	+1·063	+0·805	+0·607
+0·459	+0·609	+0·805	+0·781 +	+0·781	+0·805	+0·609	+0·459
0·346	+0·459	+0·607	+0·588 +	+0·588	+0·607	+0·459	+0·346]

Q = water volume in cu. m./sec.
A = measuring area in sq. m.
m = number of current meters
p = number of horizontals



The diagram is applicable to m and $p \geq 6$ according to the division above. For each constant in the diagram, the equation of the relative current meter $v = a + \frac{bn}{t}$ is entered; then the friction constant a is multiplied here and removed outside the bracket to be represented as a constant water volume Δq_1.

Date

Time

Test No.

Running period ..... sec. Power Station ..... Runner opening ' mm.

Gate opening mm.

TABLE II—WATER VOLUME MEASUREMENT AT

Current meter No.	8236	8237	8238	8239	8240	8241	8242	8243	8244	8245	8246	8247	
I	0·346	+0·459	+0·607	+0·588	+0·588	+0·588	+0·588	+0·588	+0·588	+0·607	+0·459	+0·346	I
II	0·459	+0·609	+0·805	+0·781	+0·781	+0·781	+0·781	+0·781	+0·781	+0·805	+0·609	+0·459	II
III	0·607	+0·805	+1·063	+1·031	+1·031	+1·031	+1·031	+1·031	+1·031	+1·063	+0·805	+0·607	III
IV	0·588	+0·781	+1·031	+1·000	+1·000	+1·000	+1·000	+1·000	+1·000	+1·031	+0·781	+0·588	IV
V	0·588	+0·781	+1·031	+1·000	+1·000	+1·000	+1·000	+1·000	+1·000	+1·031	+0·781	+0·588	V
VI	0·607	+0·805	+1·063	+1·031	+1·031	+1·031	+1·031	+1·031	+1·031	+1·063	+0·805	+0·607	VI
VII	0·459	+0·609	+0·805	+0·781	+0·781	+0·781	+0·781	+0·781	+0·781	+0·805	+0·609	+0·459	VII
VIII	0·346	+0·459	+0·607	+0·588	+0·588	+0·588	+0·588	+0·588	+0·588	+0·607	+0·459	+0·346	VIII
Rising b	0·2497	0·2484	0·2518	0·2492	0·2510	0·2494	0·2523	0·2513	0·2498	0·2490	0·2454	0·2488	
Σ column													
Σ column $\times$ b													

$$Q = \frac{A \sum \Sigma \text{ column} \times b}{73{\cdot}44t} = \qquad \Delta q_1 = \qquad \Delta q_2 = \qquad Q_{corr} = Q + \Delta q_1 - \Delta q_2 =$$

$$F_1 = a(0{\cdot}6\ x + 0{\cdot}3\ x) + \frac{b}{2}(0{\cdot}36\ x^2 - 0{\cdot}09\ x^2) + \frac{c}{3}\,0{\cdot}216\ x^3 + 0{\cdot}027\ x^3)$$

$$= 0{\cdot}9\ ax + 0{\cdot}135\ bx^2 + 0{\cdot}081\ cx^3$$

$$F_1 = 0{\cdot}9\ x\ v_1 + \frac{0{\cdot}135\,x}{24}\ (-55v_1 + 64v_2 - 9v_3) + \frac{0{\cdot}081\,x}{4{\cdot}8}(5v_1 - 8v_2 + 3v_3)$$ by substituting (4, 7, 8).

From which we obtain the following:

$$F_1 = \frac{x}{192}(129{\cdot}6v_1 + 43{\cdot}2v_2) \qquad \ldots(14)$$

F_8 by changing the indices

$$F_8 = \frac{x}{192}(129{\cdot}6v_8 + 43{\cdot}2v_7) \qquad \ldots(15)$$

The average velocity vector v_m may now be calculated from (1) as follows:

$$v_m = \frac{F + F_1 + F_8}{(m - 1{\cdot}2)\,x}$$

$$v_m = \frac{1}{(m - 1{\cdot}2)}\,(0{\cdot}58819v_1 + 0{\cdot}78056v_2 + 1{\cdot}03125v_3 + 1{\cdot}00000v_4 + 1{\cdot}00000v_5 + 1{\cdot}03125v_6 + 0{\cdot}78056v_7 + 0{\cdot}58819v_8) \qquad \ldots(16)$$

The same division is used for the horizontals, and therefore a similar formula is used vertically. The average velocity vectors of the horizontals 1, 2, 3, 4, 5, 6, 7 and 8 are indicated by $v^1{}_m$, $v^2{}_m$, $v^3{}_m$, etc. The resulting average velocity vectors for the whole measuring area will then be

$$v_M = \frac{1}{p - 1{\cdot}2}\,(0{\cdot}58819v^1{}_m + 0{\cdot}78056v^2{}_m + 1{\cdot}03125v^3{}_m + 1{\cdot}00000v^4{}_m + 1{\cdot}00000v^5{}_m + 1{\cdot}03125v^6{}_m + 0{\cdot}78056v^7{}_m + 0{\cdot}58819v^8{}_m) \qquad \ldots(17)$$

The average velocity vectors of the horizontals are now inserted in formula 17. In view of space considerations only a quarter of the diagram, which will be double-symmetrical, is written out. Furthermore, the symbols of the velocity vectors are left out.

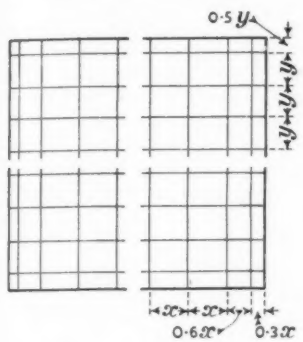
$$v_M = \frac{1}{(m - 1{\cdot}2)(p - 1{\cdot}2)}\Big[\,0{\cdot}58819\,(0{\cdot}58819 + 0{\cdot}78056 + 1{\cdot}03125 + 1{\cdot}00000 + \ldots\ldots) + 0{\cdot}78056\,(0{\cdot}58819 + 0{\cdot}78056 + 1{\cdot}03125 + 1{\cdot}00000 + \ldots\ldots) + 1{\cdot}03125\,(0{\cdot}58819 + 0{\cdot}78056 + 1{\cdot}03125 + 1{\cdot}00000 + \ldots\ldots) + 1{\cdot}00000\,(0{\cdot}58819 + 0{\cdot}78056 + 1{\cdot}03125 + 1{\cdot}00000 + \ldots\ldots)$$

After multiplication of the coefficients and insertion of the measuring area A, the fundamental diagram for the water volume Q is obtained as shown in Table I, where the numerical values have been rounded off to three places of decimals. An example of a counting diagram is shown in Table II. This diagram is applicable to 12 current meters and eight horizontals. As each current meter runs in its own column, its lifting constant b can be removed; then, for instance, by means of the fully automatic Swedish calculating machine "Facit," we can obtain the sum of the products in each column directly, whereupon the "Σ column" is noted; then these are multiplied by the current-meter constants and entered in the "Σ column $\times$ b"; finally, all the "Σ column $\times$ b" are added up and entered in the formula for Q. The figures in "Σ column $\times$ b" could possibly be ignored and instead added directly on the machine. This is certainly

TABLE III—BASIC DIAGRAM FOR WATER VOLUME MEASUREMENT (DOUBLE CURRENT RODS)

$$Q = \frac{A}{(m - 1{\cdot}2)p}\Big[$$

Q = water volume in cu. m./sec.
A = measuring area in sq. m.
m = number of current meters
p = number of horizontals



The diagram is applicable to m and $p \geqq 6$ according to the division above. For each constant in the diagram, the equation of the relative current meter $v = a + \frac{bn}{t}$ is entered; then the friction constant a is multiplied here and removed outside the bracket to be represented as a constant water volume Δq_l.

0·637	+0·846	+1·117	+1·083 +	+1·083	+1·117	+0·846	+0·637
+0·515	+0·683	+0·902	+0·875 +	+0·875	+0·902	+0·683	+0·515
+0·613	+0·813	+1·074	+1·042 +	+1·042	+1·074	+0·813	+0·613
+0·588	+0·781	+1·031	+1·000 +	+1·000	+1·031	+0·781	+0·588
+0·588	+0·781	+1·031	+1·000 +	+1·000	+1·031	+0·781	+0·588
+0·613	+0·813	+1·074	+1·042 +	+1·042	+1·074	+0·813	+0·613
+0·515	+0·683	+0·902	+0·875 +	+0·875	+0·902	+0·683	+0·515
+0·637	+0·846	+1·117	+1·083 +	+1·083	+1·117	+0·846	+0·637]

preferable when the operator is used to handling a calculating machine, for in actual fact the noting of the numerical values takes the main part of the total calculation time and should therefore be reduced as much as possible.

The small water volumes represented by the friction constants a, and which have been given the symbol, q_l, are constant for all tests and can be calculated quite simply by multiplying the sum of the constants for each column by the respective friction constant as before. If double current-meter rods are used, the number of horizontals must be even because two current meters will then run in each column. The two current meters in the respective columns ought to be paired, so that the lifting constants become as nearly equal as possible, and in fact an average lifting con-

TABLE IV—WATER VOLUME MEASUREMENT AT ..... POWER STATION

Date							Test No.	
Time							Runner opening	°
Running period	sec.						Gate opening	mm.
Current meter No.	8245	8240	8238	8236	8237	8239	8242	
	8246	8249	8243	8244	8247	8241	8248	
I	0·637	+0·846	+1·117	+1·083	+1·117	+0·846	+0·637	I
II	0·515	+0·683	+0·902	+0·875	+0·902	+0·683	+0·515	II
III	0·613	+0·813	+1·074	+1·042	+1·074	+0·813	+0·613	III
IV	0·588	+0·781	+1·031	+1·000	+1·031	+0·781	+0·588	IV
V	0·588	+0·781	+1·031	+1·000	+1·031	+0·781	+0·588	V
VI	0·613	+0·813	+1·074	+1·042	+1·074	+0·813	+0·613	VI
VII	0·515	+0·683	+0·902	+0·875	+0·902	+0·683	+0·515	VII
VIII	0·637	+0·846	+1·117	+1·083	+1·117	+0·846	+0·637	VIII
Average rising b	0·2472	0·2509	0·2516	0·2497	0·2486	0·2493	0·2528	
Σ column								
Σ column $\times$ b								

$$Q = \frac{A \Sigma \Sigma \text{ column} \times b}{46{\cdot}4t}$$

$\Delta q_1 =$ $\Delta q_2 =$

$Q_{corr} = Q + \Delta q_1 - \Delta q_2 =$

stant should be calculated. Once this is done, the current-meter pairs for which the lifting constants differ most should be placed at the terminal positions, because they are then in that portion of the measuring area which has least effect on the result, and consequently cause the least possible error. Also, when using double current meters it is necessary to place the upper and the lower horizontals at a distance of $0{\cdot}5y$ instead of $0{\cdot}3y$ from the wall. It is also desirable that $0{\cdot}5y$ should not be appreciably greater than $0{\cdot}3x$. As a result of this use of double current meters there will be more horizontals, which is disadvantageous from a time point of view, but we need not attach too much importance to this, because by using double current-meter rods the total time to carry out a test is reduced by nearly half. A greater number of measuring points also helps to cancel out the variations in water flow, so that the total measuring time per horizontal can be reduced to a certain limiting value. A basic diagram using double-current meter rods is shown in Table III, and a practical example applicable to 14 current meters and eight horizontals may be found in Table IV.

The symbol Δq_2 refers to the so-called edge correction caused by the reduction of the water velocity in the zone next to the boundaries of the measuring area. This can be simply calculated by using a formula drawn up by the Vattenbyggnadsbyrån, Stockholm.

It is not possible to use this term in the calculating diagram, but it can be replaced by a more approximate one which is probably quite sufficient from an accuracy point of view if the boundaries of all measuring areas have about the same length in the direction of flow. However, it is usual for intakes and specially designed measuring nozzles (the latter often used in Sweden) to vary in length in the direction of flow; in this case, the insertion of the approximate edge correction in the calculating diagram may sometimes give rise to doubts as to why this simplification, which in fact is not very important, has been omitted.

It will be clear from the fact that the vertical lines between the three outside lines are equal, that the diagram is applicable to an optional number of current meters from six upwards. The same also applies to the horizontals.

(To be continued)

The Snowy Mountains Scheme

The Snowy Mountains scheme is such a mighty undertaking that no single paper could hope to deal with it exhaustively, but Mr. C. M. Gray, Senior Representative of the Department of National Development, Commonwealth of Australia, succeeded in presenting an admirable summary of it in a paper he presented a month ago to The Royal Society of Arts. Mr. Gray was concerned mainly with the significance of the scheme in the Australian economy and with an account of the progress made to date, and to leave himself scope in this direction he contented himself with a bare outline of the technical details of the scheme, relegating fuller description to an appendix.*

Mr. Gray commenced by stressing the dual-purpose nature of the scheme, for Australia's economy depends both on ample irrigation and on ample reserves of power. He estimated that the additional agricultural production that would be made possible by irrigation from the Snowy scheme would be worth ultimately about £A25 million. From the power standpoint the scheme would have an ultimate capacity of about 3,000 MW and would act primarily as a source of peak-load supply for the States of New South Wales and Victoria to supplement the base loads carried by thermal stations, although it would also act as a base-load reserve in emergency.

An interesting comparison between Snowy and two other great Commonwealth schemes—Kitimat and Kariba—showed that the Snowy scheme was of about twice the capacity of either of the others and was much the most complex, due to the need to harness the various streams almost at their sources.

Basically, the scheme consists of diverting the waters of the Snowy River from the well-watered eastern flank of the Australian Alps through the watershed to the Murray and the Murrumbidgee, which flow through the comparatively arid regions of central and southern Australia. It is divided, therefore, into two main developments—the Snowy-Murray and the Snowy-Tumut, the Tumut being a tributary of the Murrumbidgee.

The 60 MW Guthega station, in the Snowy-Murray development, was now in operation, and activity was now centred in the Snowy-Tumut development. Works in hand included the Adaminaby dam, the 14 mile Eucumbene-Tumut diversion tunnel, a concrete arch dam on the Upper Tumut River, and the T1 power station together with a $1\frac{1}{2}$ mile pressure tunnel and a $\frac{3}{4}$ mile tailrace tunnel. Next on the programme was the Tooma diversion, and the T2 station was being planned.

Mr. Gray also had some interesting things to say about the system of Commonwealth-State co-operation under which the scheme had developed, and about the magnitude of the initial task of surveying and establishing access to the area and of setting up the necessary technical organisation.

* A full description of the Snowy Mountains scheme was given in WATER POWER, April, May and June, 1953.

Voith, Forschung und Konstruktion (Research and Design). The first issue to hand of this new publication of the J. M. Voith concern, Heidenheim/Brenz, contains a series of articles of the highest interest, among which we should like to mention: "Vertical or Horizontal shaft in Storage Pumping Sets," by F. Hartmann; "A Contribution to the Study of the Hydraulic Behaviour of Kaplan Turbines" (run-of-river plants only are considered), by R. Dziallas; "Considerations on Flow Measurements in Kaplan Turbines," by W. Thuss; "Bearings, Regulation Components and their Lubrication in Water Turbines," by L. Meissner; "Investigating the Critical Speed in a Kaplan Turbine-A.C. Generator-Exciter Set," by S. Weiss; "Significance of the Radial Velocity components of Water in Kaplan Turbines," by M. Strscheletzky; "Modern Kaplan Turbines," by L. Meissner; "Application of Turbines to the Aeration and Oxygenation of River Water," by H. Wagner.

Tidal Power

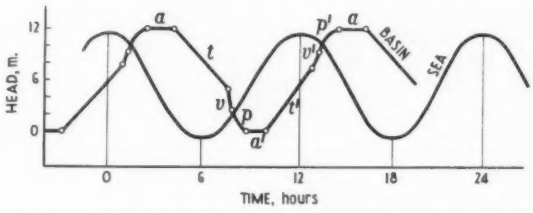
Dr.-Ing. Gerhard Wickert, Dortmund, Dozent at the Technical University, Karlsruhe, outlines the fundamentals of tidal power, and reviews current trends in the design of turbines and civil-engineering structures suitable for this service

PART ONE

TO the seashore dweller the ebb and flow of tides is a familiar phenomenon of nature. Tides are, as it were, the breathing of the sea, the pulse of the cosmos, which gives life to the oceans of the world and sets them in motion; and, since the remotest ages, this mystery has haunted the mind of man and stimulated his heart and brain to meditate and search.

The cosmic potential which manifests itself in the tides is so immense that, in comparison, the totality of the energy won up to the present from water appears trivial. A rough computation proceeding from a mean tide height of 0·7 m. arrives at an aggregate total output of some 54,000 million h.p., whereas the possible output of the continental water resources of the whole world does not exceed 7,600 million h.p. —a mere seventh of the tidal potential.

Attempts to utilise the potential and kinetic energy offered by the perennial rhythm of ebb and flow goes very far back in history. We meet with the first instance of a practical realisation of the problem on a very small scale in the shape of the so-called tide mills, which made their appearance as early as the eleventh century. Grinding corn or gypsum, or sawing timber, these were floating contraptions in which an undershot waterwheel utilised only the kinetic energy of the tidal flow. The oldest work on the utilisation of tides was



BASIN-TO-SEA FLOW		SEA-TO-BASIN FLOW	
TURBINE IN ACTION t	BASIN SEA	TURBINE IN ACTION t'	BASIN SEA
NO LOAD v	BASIN SEA	NO LOAD v'	BASIN SEA
PUMP IN ACTION p	BASIN SEA	PUMP IN ACTION p'	BASIN SEA
IDLE TIME a	BASIN SEA	IDLE TIME a'	BASIN SEA

Fig. 1 (above). Cycle diagram for a two-way single-basin plant

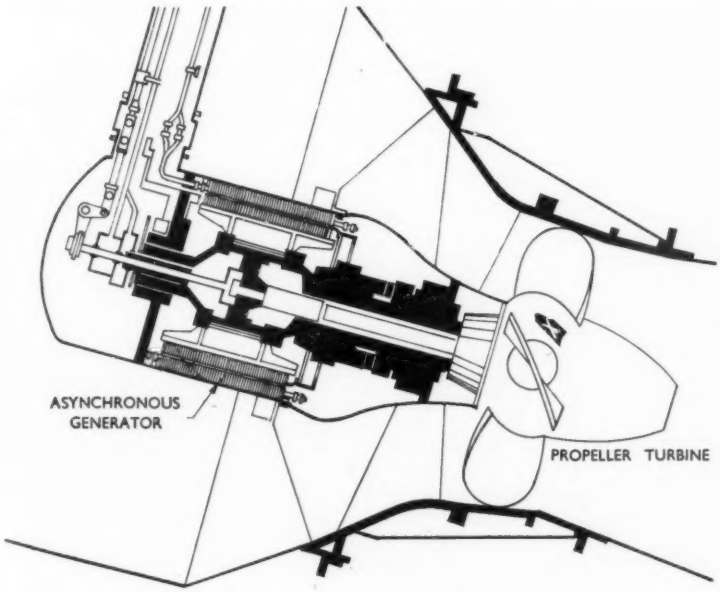


Fig. 2 (left). One-way tubular turbine for the Castet plant

written in 1438 by the Italian Mariano, of Siena, and includes, in addition to sketches, constructional hints. Brooklyn still boasts today of one of these tide mills built in 1617 by Dutch colonists after the plans of another Italian, Veranzio. Upon the advent of the steam engine, the interest in tide mills soon vanished, and the problem of tidal power did not re-emerge earlier than in the twentieth century. In 1912, the German engineer Pein made some stir with his proposal to set up a tidal power plant at a particularly favourable spot on the North Sea coast. In

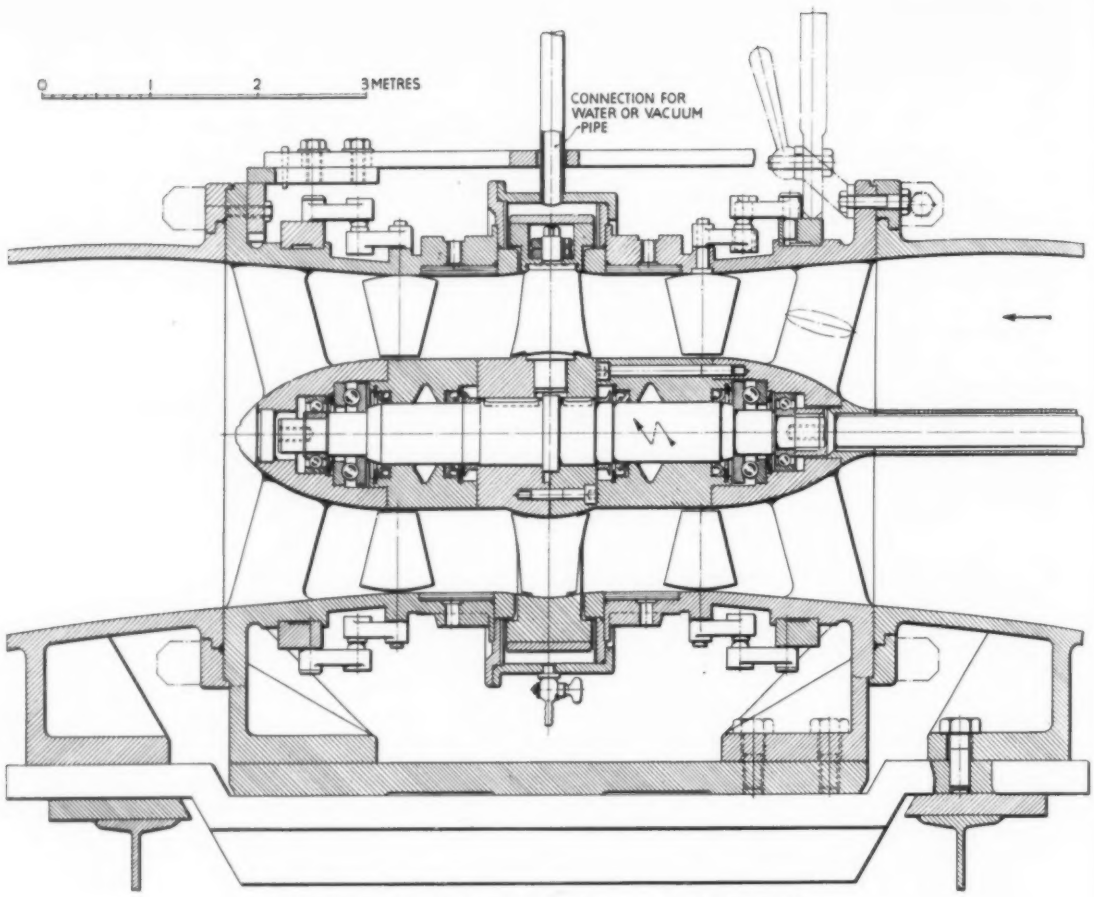


Fig. 3. Longitudinal section of two-way tubular turbine

Great Britain, a few years after World War I, preliminary projects came out for the Severn, followed by schemes for two tidal plants in the vicinity of Liverpool. In France as well, the import of this heretofore untapped source of energy was promptly recognised, and suggestions were made to harness tides to power generation with the help of the technical means available at the time. The first major project, also worked out after World War I, is based on the very favourable conditions obtaining in the Bay of Rotheneuf at Cape Bénard. Subsequently, all these tidal schemes sank more or less into oblivion, and it appeared from various publications on the subject that an economical harnessing of tides to power generation was still very far away.

This brief historical survey is proof enough that some significance had been granted at an early juncture to the problem of tidal power, and at the present period of intensive search for new sources of energy, it is perfectly natural that we should endeavour anew to bring the problem to a satisfactory solution. After all, as proved by the evolution of public and industrial consumption during the past 40 years, the saturation point of energy requirements is still very far ahead. To mention Western Germany only, it is expected that her present needs will double within the next ten years, and this may well apply to the rest of the world.

With numerous harnessable rivers already developed to the full and the increasing scarcity of convenient sites for the setting up of further medium and high-head plants, with thermal plants paying now for their coal four times as much as in 1939 and hardly able to improve their efficiency, and with the economical production of atomic power still very far distant, conditions are veering more and more in favour of tidal power.

A closer investigation of the possibility of harnessing tidal power reveals an amazing multiplicity of overlapping problems for which practical solutions are by no means as simple as appears at first sight. Further, traditional hydro-electric practice applies only conditionally to tidal plants, in the working of which, cosmic forces intervene to a very wide extent. We must therefore realise that no economical and practical solution of the problem can be arrived at without a close co-operation of the astronomer with the hydrographer, and of the hydraulic with the mechanical and electrical engineer, not to mention the economist.

To what extent can we harness tidal energy ? Since velocities of tidal flow, however high the tide, are always very small, the utilisation of the kinetic energy of tides would hardly be worth while; we shall therefore restrict our investigation to the exploitation of potential energy only.

One-way Operating Tidal Plant

Let us consider the case of a basin separated from the sea by a dam, the water level in the basin following the rise and fall of the sea, and let us call H the tide height, and V the capacity of the basin at the corresponding water level. For a basin area $S(z)$ as a dependent variable of water level z in the basin, the work performed during the emptying period will be

$$E^{I}_{B} = \int_{z=0}^{H} \gamma S(z) z dz \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and during the filling period

$$E^{II}_{B} = \int_{z=0}^{H} \gamma S(z)(H - z) dz \quad \ldots\ldots\ldots\ldots (2)$$

emptying and filling the basin occurring necessarily within a tide interval during which the level of the sea rises from 0 to H. The available energy capacity during a whole tidal cycle would then be

$$E^{I}_{B} + E^{II}_{B} = E_{Bth} = \gamma H \int_{z=0}^{H} S(z) dz = \gamma H V_{B} \quad \ldots (3)$$

Actually, however, the practically utilisable energy is but a fraction of the above ideal value, so that the theoretical extent to which the energy capacity can be utilised is limited to

$$E_{B} = \delta \gamma H V_{B} \text{ where } \delta < 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

With the help of artificial means, however, it is possible to arrive at a much higher degree of utilisation.

As soon as the rising tide reaches its highest point, sluice gates in the dam are opened to admit water at high velocity into the empty basin, and subsequently closed as soon as the basin is filled. Taking into account the surges occurring in the basin while being filled, test models have established that a storage level of $1{\cdot}5H$ can easily be attained. Theoretical considerations point out to a value of $2H$ in the instance of a channel trapezoidal in cross-section; as however

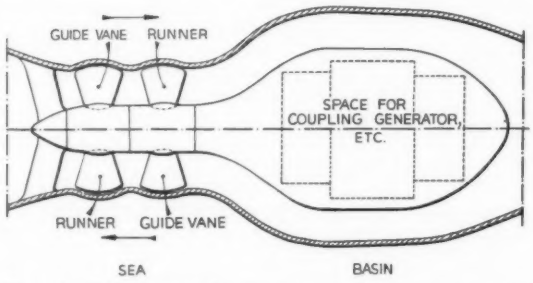


Fig. 4. Diagrammatic arrangement of two-runner turbine-pump

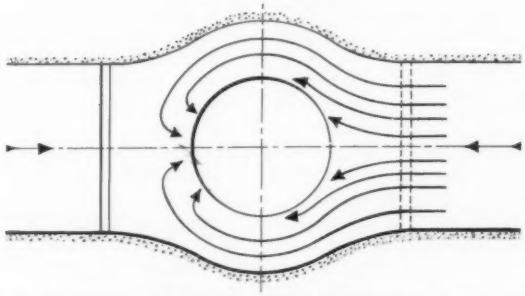


Fig. 5. Double-admission entry chamber for vertical Kaplan turbine

there is no energy generation during the filling period, the possible energy output can only relate to the emptying period, that is to say to the ebb half of the tidal cycle, and we obtain

$$E_{Bth} = \tfrac{1}{2}\gamma S(2H)^2 = 2\gamma H V_{B} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Therefore, in the most favourable instance and with the surges being utilised to the full, twice as much energy can be produced as would normally be possible on the basis of the available tide height.

The above considerations apply exclusively to plants operating with turbines only, and utilisation possibilities are substantially modified by the addition of a pumping system. If, for instance, we have to deal with the case of a one-way plant operating with turbines and pumps, then we may have, in addition to the main basin, an auxiliary basin $F(z)$ $(z \geqq H)$ with its bottom lying at the level of tide height H. While the incoming tide fills the main basin, the pumps coupled to the turbines lift water into the auxiliary basin to level B. If the turbines and pumps are of equal capacity, we then have

$$\int_{z=0}^{H} \gamma S(H - z) dz + \int_{z=H}^{B} \gamma F(z - H) dz \quad \ldots\ldots\ldots\ldots (6)$$

and if we express the pumped volume of water by V_{p}, equation (6) expands to

$$E_{Bth} = \int_{z=0}^{H} \gamma S z dz + \int_{z=H}^{B} \gamma F z dz = \gamma H (V_{p} + V_{B}) (7),$$

the theoretical energy produced during the ebb period by the water flowing out of the two basins being thus greater by $\gamma H V_{p}$ than in the case (3) of a plant operating with turbines only.

Two-Way Operating Plant

In a plant operating with double-admission turbines and two-way pumping, and in the general case of a single basin without higher auxiliary basin, the pumps drawing their power from the network, we have the following four phases:—

(a) The water level in the basin, equal to low water level, being further lowered to $-B$ by pumping, the pumps will draw from the network

$$E_{p1} = \int_{z=0}^{-B} \gamma S(z) z dz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

(b) The rising tide fills the basin, and the energy output of the turbine is

$$E_{T1} = \int_{z=-B}^{H} \gamma S(z)(H - z) dz \quad \ldots\ldots\ldots\ldots (9)$$

(c) Upon high water level being reached, the pumps raise the water level in the basin to level C with an energy consumption of

$$E_{p2} = \int_{z=H}^{C} \gamma S(z)(z - H) dz \quad \ldots\ldots\ldots\ldots\ldots (10)$$

(d) The turbines utilise the water in the basin down to level 0, during which period their energy output is

$$E_{T2} = \int_{z=0}^{C} \gamma S(z)(z - H) dz \quad \ldots\ldots\ldots\ldots (11)$$

This, after deduction of the requirements of the pumps, leaves for an operating cycle an energy production of

$$E_{Bth} = E_{T1} + E_{T2} - E_{p1} - E_{p2} = \gamma H \int_{z=-B}^{C} S(z) dz$$

$$= \gamma H (V_{B} + V_{p1} + V_{p2}) \quad \ldots\ldots\ldots\ldots (12)$$

Therefore, if turbines and pumps operate at both

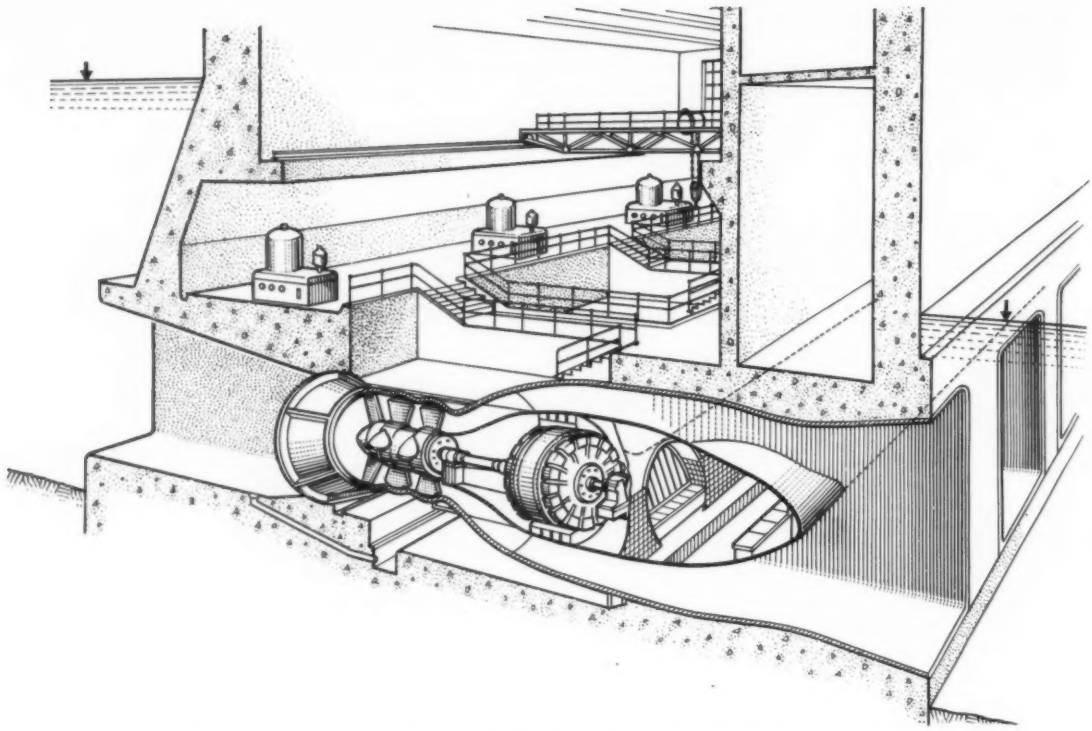


Fig. 6. Perspective view of tidal power house showing one of the two-runner turbine-pump units

flow and ebb periods, the energy gain to be expected amounts to

$$\gamma H (V_{p1} + V_{p2})$$

as against turbines exclusively in operation (Eq. 3) and

$$\gamma H V_{p2}$$

in the case of one-way pumps delivering into a higher auxiliary basin.

The judicious selection of the sea-dam site in a bay or estuary makes it possible, by taking advantage of resonance, to increase the tide range during a tidal cycle, since each basin has a natural frequency of its own depending on its size and proportions. In a basin of a length of l metres, with a rectangular cross-section and a depth t, the natural frequency is expressed by $T = 2l/\sqrt{gt}$. When the natural frequency of the basin approaches the frequency of the tide, the tidal impulses which set the water in the basin into oscillation are reinforced. There is then the possibility, as proved by computation, of tide-range increases up to 10 per cent.

Types of Tidal Developments

Among the various basin systems, such as one-way or two-way single basin, single basin with auxiliary basin, two basins operating together or separately, three basins with intermediate chamber, Defour's three-basin system, and others, the two-way operating single-basin development, thanks to the advance of turbine-pumps, offers an economically satisfactory solution. In this system a basin of appropriate size separated from the sea by a dam, fills and empties solely through the power house. As, in contrast to other systems, no additional sluice-gates or intermediate dams are required, this considerably simplifies the construction, and the plant can be operated much more easily. Once the high tide begins to fall and the level of the water in the basin stands above sea level (Fig. 1, condition *a*), the turbines are started as soon as the required head is available (point 1), and pass the water of the basin down to a minimum level (point 2). By adjusting the guide and runner vanes, the turbine runs idle (condition *v*), the water continues to run out of the basin, and, subsequently, the turbine operates as a pump, the water level in the basin sinking below sea level (condition *p*). Following a waiting period (condition a^1), during which the direction of the flow is reversed and the flood tide starts afresh, the turbines, operating under load from the sea side (condition t^1), utilise the head available to point 4. After a period of idle running (v^1), and the subsequent pumping (p^1) and a waiting period (*a*), the working cycle begins again.

In the case of a single-basin system operating with turbine-pumps, the periodical fluctuations of the level of the sea bring about in each tidal cycle two periods during which there is no energy production (Fig. 1). There are various methods of output equalisation, such as multi-basin systems, retaining basins, co-ordination of a group of tidal plants operating at staggered high-water periods, pneumatic, thermal or electric accumulation, but their practical application is restricted to a few exceptional instances, and they are mentioned here just for the sake of completeness. If the plant is connected to a grid, it then operates in the same way as a run-of-river development to cover part of the firm load. Since the cause of ebb and flow is of an astronomic nature, their progress and, con-

sequently, the possible output of tidal plants, can be computed years in advance with great accuracy, and the organic incorporation of a tidal plant in a grid only requires the setting up of a timetable and central control point. Steep coasts frequently offer the possibility of adding a storage pumping station to the tidal power plant, thus creating an equalisation of output within the co-ordinated group of plants. A rational control of the supply of power water to the turbines or its return to the basin by pumping will improve the output of either the power house or the pumping plant, according as the running period of one or the other coincides with the main load period of the grid.

The conditions to be met by tidal turbines differ essentially in some respects from those obtaining for run-of-river turbines operating on inland waters. In consequence, the types of turbines generally used in run-of-river plants are not fully suitable for tidal duties. The turbine shaft can be either horizontal, as in the tubular turbine, or vertical. The tubular turbine has the advantage of a favourable flow both at entry and exit, resulting not only in better discharge conditions but also in lower costs. Leaving aside a survey of the evolution of this turbine type, the author proposes to deal here only with the most recent designs.

The latest plant equipped with tubular turbines is the Castet power station in the French Pyrenees. These units are of the single-discharge type, operating purely as turbines and not as turbine-pumps, but they present the remarkable feature of an uncommonly small size. In fact, at Castet, the weight of a complete generating unit (turbine plus generator) is a mere fifth of that of a set of the same capacity driven by a standard vertical-shaft Kaplan turbine. The erection of the Castet generating sets required only a few hours per unit, turbine and generator forming a self-contained unit. Dismantling is even quicker so that repairs can easily be carried out during the interval between two peak periods (see Fig. 2).

In Fig. 3, we have the double-discharge type of turbine designed and model-tested by the Escher-Wyss concern, in which two sets of movable guide vanes, fitted one on either side of the runner, regulate admission to the latter; at an appropriate position of the vanes, this turbine can also act as a pump.

The type introduced by the Maier Engineering Works and A. Fischer (Figs. 4 and 6) is an adjustable two-wheel turbine-pump, also operating in either direction of the flow as a turbine or a pump, as required. The turbine-pump and its hydraulically coupled generator are enclosed in a cylindrical tube widening at one end to a bulb-shaped section designed in accordance with wind-tunnel tests. The respective duties of the guide vane and runner are fulfilled either by the front or by the rear wheel according to the direction of the flow. These have adjustable and reversible vanes, and can be thrown in or out independently of each other. At a given position of the vanes, it is even possible to stop the flow through the turbine altogether. Determining the correct shape of the blades in this type of turbine-pump proved a difficult proposition, since, at normal turbine operation, it is the front of the blade which is acted upon by the flow, and at pumping periods, the back. Separation of the water-layer from the guide vanes and cavitation at the runner occurred to some extent during the initial tests, but practically disappeared after some improvements had been made in the construction of the model turbine.

In vertical-shaft turbines, conditions are much more complex. If we take, for instance, a Kaplan turbine with alternate flow admission from two directions, the inlet half-scroll common to most low-head plants is ruled out, owing to its asymmetric form, but even a heart-shaped symmetrical inlet would not substantially improve flow conditions. The adoption of an inlet chamber has the advantage of leading the flow to the guide vanes symmetrically in either direction; if the flow velocities are kept adequately small, losses do not exceed admissible limits. Considered from the aspect of engineering technique, the advantages of this pattern of turbine-pump should in no way be disregarded (Fig. 5).

(To be continued)

M.A.N. Documentary Film

One of the finest documentary films we have seen has been prepared by M.A.N. (Maschinenfabrik Augsberg-Nürnberg), and the English version, for sight of which we were indebted to W. Wykeham & Co. Ltd., had been provided with a commentary in perfectly spoken English. The film, which was in colour, showed how mankind is indebted to engineering in a bewildering variety of ways, and the fact that the bewildering variety of steel products portrayed had all been made by the M.A.N. organisation was conveyed so unobtrusively and with such good taste that the impression left on us was simply one of delight. Our own particular interest, of course, lay in the hydraulic steel structures that this firm has contributed to so many hydro-electric schemes, but to single this out from such a galaxy of interesting things seems little short of churlish. We congratulate the M.A.N. organisation on so fascinating a production.

Sealing Compounds. A leaflet from Expandite Limited gives a list of the many sealing and caulking compounds they manufacture for joints in concrete, brickwork, etc., as well as waterstops, concrete waterproofing agents, etc. A separate leaflet refers to the properties of Aerolastic, used particularly for sealing joints in airfield runways and in garage and factory floors.

Storfinnforsen and Laforsen Power Stations. A descriptive brochure, excellently produced in colour, has been sent us by Nydqvist & Holm A.B., Trollhättan, Sweden, giving full details of the turbines they have supplied to Storfinnforsen and Laforsen power stations. Storfinnforsen station, owned by Krångede A.B., is on the Ångerman, and has three 47,000 h.p. machines operating under a head of 48·5 m. Laforsen station, on the Ljusnan, is owned by Stockholms Superfosfat Fabriks A.B., and contains two 21,500 h.p. turbines operating under 34 m. head. The efficiency curves obtained at the official acceptance tests are given for both stations, and in each case is well above the guaranteed curve; the maximum efficiency at Storfinnforsen was determined at 93·1 per cent. and at Laforsen 92·6 per cent. The brochure is published in Swedish, English and Spanish.

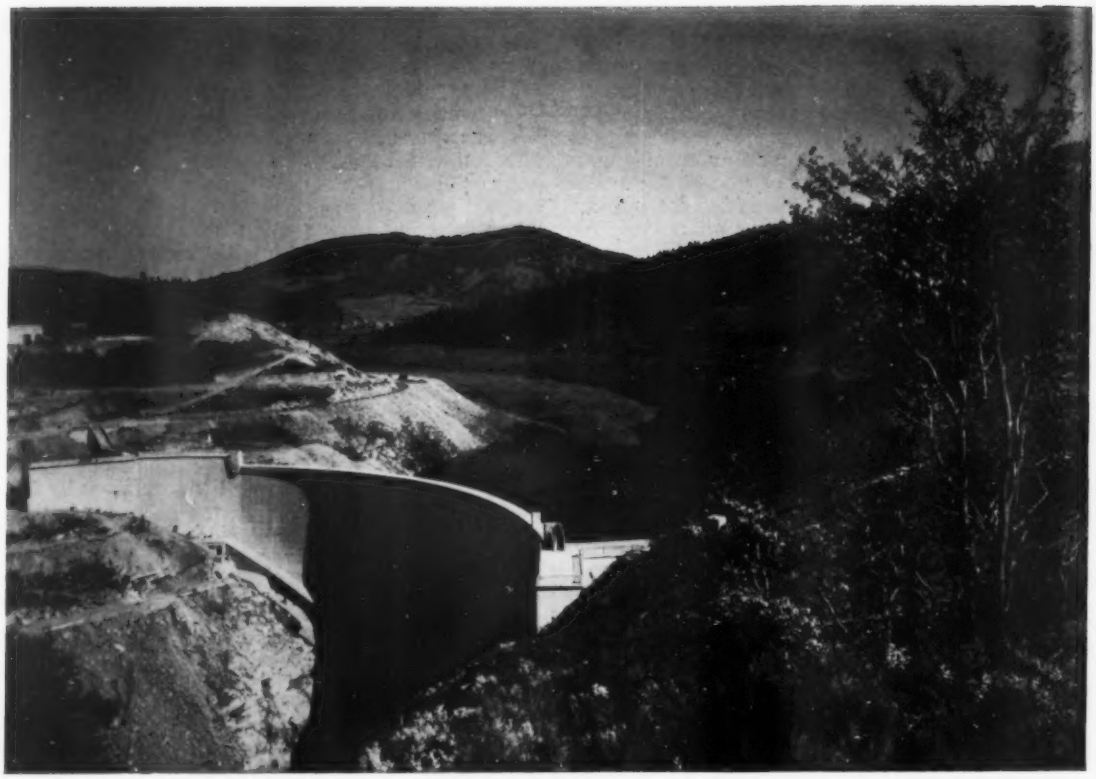


Fig. 13. La Palisse dam, the largest in the scheme, as completed

The Montpezat Scheme

The previous article the writer outlined the main features of the Montpezat scheme as a whole, and described the underground power station. Unusual interest attaches to the dams, reservoirs and tunnels associated with the scheme, and these will now be discussed

By WALTER T. STOREY, B.A. (Cantab.)

PART TWO

La Palisse Dam. This is the largest of the dams and controls a 131 sq. km. watershed with a useful storage capacity of 7·8 million cu. m. The dam is of the thin-arch type with a crest length of 170 m., a radius of 90 m., a 90° elevation angle and a maximum height of 55 m. above river bed level. Some 30,000 cu. m. of concrete were used in the construction of the dam, which, like many other dams in France, has the central portion designed to serve as a spillway, in this instance capable of dealing with 700 cu. m. of flood water per second.

La Veyradère Dam is a simple intake structure with a negligible storage capacity. The central part of the crest is designed to act as a spillway capable of dealing with 180 cu. m. per sec., and other leading particulars are as follows:—

Extent of watershed	28 sq. km.
Maximum height above river bed	12·5 m.
Length of crest	45·0 m.
Volume of concrete used	1600 cu. m.

The Gage Dam. The Moulin de Peyron dam on the Gage is of outstanding technical interest and whereas it is not an essential part of the Montpezat scheme, it represents a most important step in the evolution of

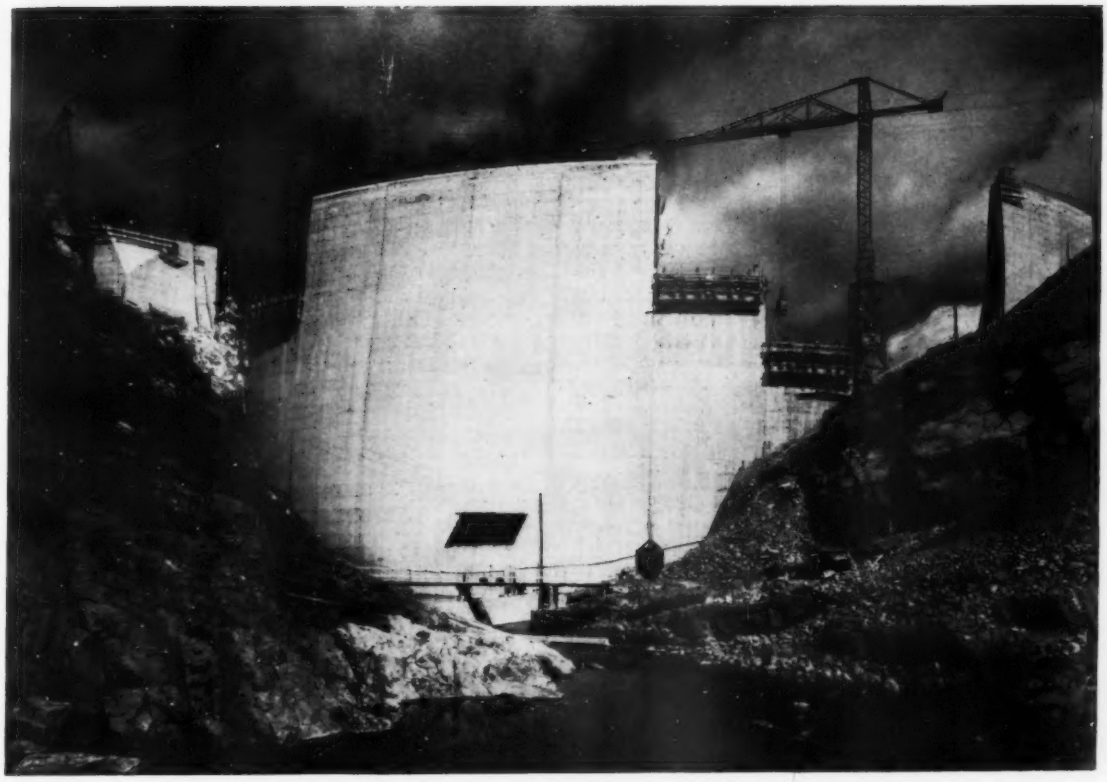


Fig. 14. View from upstream of La Palisse dam under construction

the design of dams. It is of the arch type but its novelty lies in the exceptional thinness of the structure and the exceptional stresses for which it has been designed. From first principles it is evident that the relative thickness of a structure of this kind is inversely related to the magnitude of the stresses which will be set up in the concrete of which it is composed. Hitherto the concrete of similar dams had rarely been subjected to stresses of over 50 kg. per sq. cm. and figures of this order have, in fact, only been attained quite recently. The Gage dam has been designed to withstand average stresses of over 100 kg. per sq. cm.—a virtual doubling of normal practice—but nevertheless well within the test capacity of the material. The significance of this increase in the magnitude of the admissible stress lies in the possibility of reducing the thickness of the dam and hence the volume of concrete employed. The need to economise in material is especially important in view of rising costs and the expense of transporting it to remote sites, but a justification of the thin-arch dam lies in the fact that, according to French experience, this type of dam, in spite of the more complicated constructional processes required, costs very little more per cubic metre than a corresponding gravity dam.* At any rate in France during the last ten years 26 arch dams have been built in comparison with only four of the gravity type.

It was primarily the excellence of the site which allowed the possibility of constructing a dam of such an experimental type. The cross section of the valley is narrow and moreover it is also symmetrical. The granitic bedrock proved to be sound with the exception of the right bank. A number of clay-filled faults which were encountered were sealed off with little difficulty by means of deep injections. A grouting screen completed the sealing operations; all this injection work was carried out during the period of optimum frost so that it caused no delay.

The Gage dam was designed by M. André Coyne who also acted as consulting engineer. The characteristic measurements of the dam are as follows:—

Maximum height above the river bed (m.)	38
Total length of the dam crest (m.) ...	148
Elevation angle subtended by upper arc	134°

* Paper by Messrs. H. Hupner, J. Duffant and J. Bellier presented to The Fifth International Congress on Large Dams, Paris 1955.

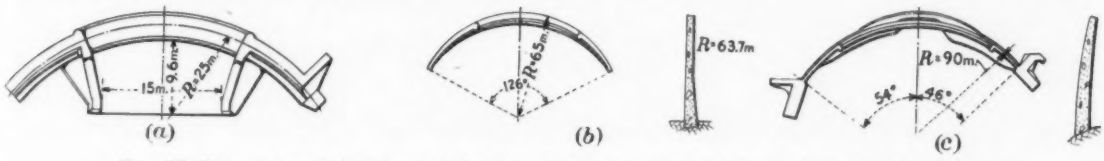


Fig. 15. Dimensioned drawings of the three dams: (a) Veyradère, (b) Gage and (c) Palisse

Thickness at crest (m.)	1·30
Maximum thickness at the base on the centreline of the dam (m.)	2·57
Volume of concrete employed (cu. m.)	4500
Useful capacity (million cu. m.)	3·3
Extent of watershed (sq. km.)	41

The spillway occupies 66 m. of the crest and is designed to allow the passage of a 250 cu. m. per sec. flood with a 1·50 m. rise of the water level. The structure is divided into 13 vertical blocks each of which is about 12 m. in length. Two drainage valves were built into the foot of the dam and are capable of draining 26 cu. m. per sec. under the full head. These two valves alone would not, however, have been capable of dealing with a sudden flood during the initial filling of the dam. This filling was planned to take place very slowly so that a series of measurements could be taken and an estimate of the stability of the structure be made. As a preliminary precaution provision was made against any sudden rise of the water level by the construction of an emergency conduit. This was fitted with a plug which could be blasted out by an explosive charge in case of need.

The concrete used in the Gage dam was naturally the subject of special study. Emphasis was laid not so much upon the production of a special type of concrete as upon a very thorough testing to ensure consistency and uniformity of results. A laboratory was set up at La Palisse where the necessary equipment was installed at an existing quarry. It was decided to manufacture the concrete here and transport it to the Gage site. In all, the laboratory handled over 900 test cubes from carefully selected samples. As a further check the concrete was used in the right-hand abut-

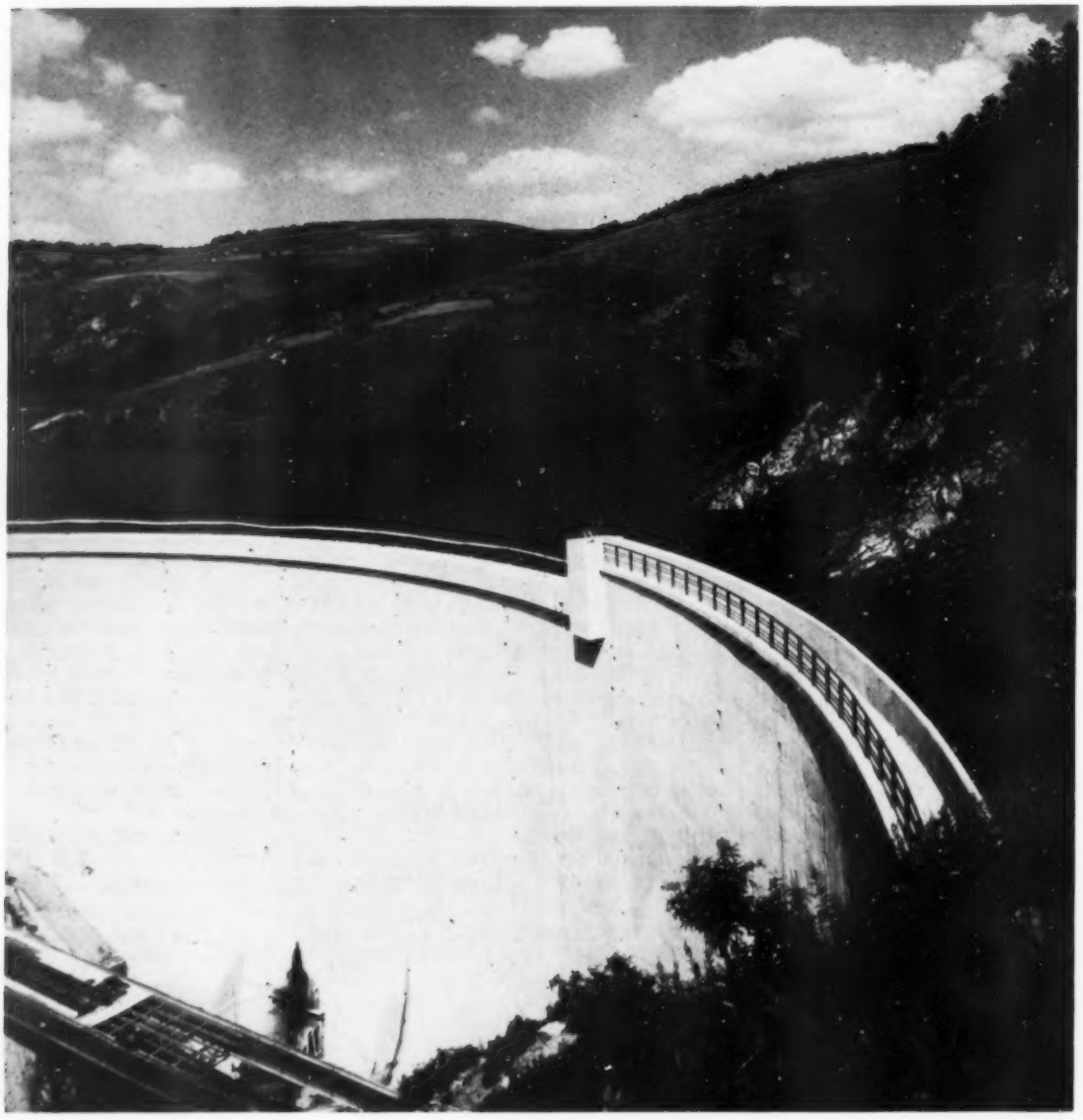


Fig. 16. Gage dam, one of the thinnest arch dams in the world

Fig. 17. Jumbo carrying five drills, as used for most of the tunnelling

ment of the La Palisse dam and as the core-drill samples taken from this proved to be 10 per cent. stronger than the test cubes, this gave the additional assurance of the adequate strength of the material when used on site. The elaborate testing at the La Palisse laboratory ensured that no concrete was used without having a minimum resistance of 300 kg. per sq. cm. after 90 days and the average resistance of the concrete employed was shown to be over 350 kg. per sq. cm. after this period. The total amount of concrete used—4,500 cu. m.—is remarkably small for a dam of this size, as will readily be acknowledged, and it was all placed during the three summer months of 1953. The pours were limited to a maximum lift of 1·5 m. and very special care was taken with the vibration technique.

The properties of the Gage dam have been most carefully studied with a view both to checking the stability and to gaining some idea of the actual, compared with the theoretical, behaviour of the structure. To these ends the examination has been conducted upon two lines. In the first place, steps have been taken to detect major geometrical deformations such as radial and tangential deflections of the whole structure, or any rising of the crest. Deflections have been measured by triangulation on two points on the downstream side and movement of the crest may be detected by visual alignment methods. In the second place, provision was made for the assessment of localised strains in the concrete and in particular those stresses resulting from changes of load. For this purpose over a hundred Telemac gauges of the " acoustic strainometer " type of vibrating cord extensometer were disposed in groups of three along four horizontal arcs in proximity to the upstream and downstream faces; in addition a few were also placed in the foundations and on the vertical steel reinforcing bars.

Extensometrical (some 10,000 of these) and triangulatory measurements were made from the outset but particularly in relation to the following basic conditions: (1) Constructional period; (2) a slow first filling which was completed in three months; (3) a rapid emptying; (4) a rapid filling which was effected in three days.

The testing campaign was greatly aided by coupling up the relatively small capacity reservoir behind the dam with the large reserve of Lake Issarlès. Expert analysis of these results has revealed the Gage dam to be entirely satisfactory. Some discrepancies between the predicted and actually observed reactions of the structure show, however, that present theories of thin-arch dam construction may need revision.

A general interpretation of this experiment shows, for example, that the arch tends to become more truly elastic after a general settling of its foundations.

The success of the Gage dam is indeed a tribute to the team of experts who brought it into being. In the future we shall expect to see the further development of this type of structure where the natural conditions permit. Nor is the economy in the concrete volume the only recommendation it possesses, as it would appear,

Fig. 18. A general view of Lac d'Issarlès

on the whole, to be safer than its gravity-type counterpart. Furthermore, the admissible stress limits of concrete have not yet been fully approached and a still further evolution along these lines may reasonably be foreseen.

Storage Reservoir at Issarlès

The addition of the storage capacity provided by the Lac d'Issarlès adds substantially to the importance of the Montpezat project. The lake has a useful capacity of 34 million cu. m. and thus represents about 75 per cent. of the total storage capacity of the scheme.

The Lac d'Issarlès occupies an ancient explosion crater of a volcano. It has a maximum depth of 108 m. and when the water level stands at an elevation of 1,000 m. the surface area of the lake is approximately 90 hectares (220 acres). Before its inclusion in the scheme the lake had no outlet so that evaporation presumably balanced with the run-off of the 4 sq. km. of its natural watershed, together with infiltrations from other sources. It was planned to utilise the storage capacity by introducing waters from the Loire, Gage and La Veyradère by means of a tunnel piercing the lake floor. The holing through of the tunnel into the Lac d'Issarlés proved to be an operation of considerable complexity but one which was met with appropriate ingenuity by the engineering staff.

A preliminary bathymetric survey of the lake floor was combined with a series of borings made by a chilled-shot core drill mounted on a raft. It soon became evident that the greater part of the lake floor was unsuitable for this piercing operation. The flatter parts of the floor were covered by a thick layer of alluvium and the slopes were overlain by screes. Towards the northern end, however, the slopes appeared to be steeper and the presence of a sheer granitic outcrop above the level of the lake gave some hope of its continuance under water. A detailed inspection of the region revealed the presence of a suitable vertical cliff of granite.

The series of operations which were subsequently carried out proved to be the most satisfactory economic answer to the conditions encountered. The vertical shaft for the intake gate was driven in from an elevation 1,004 m. along the axis of the future diversion tunnel. At an elevation 984 m., however, the inflow from the diaclase exceeded 70 litres per second and work on this shaft had to be temporarily abandoned until the diversion tunnel could drain off the water. This and further work had to be carried out beneath the protection of a series of umbrella-like injection screens. The tunnel for the provisional opening was cautiously driven forwards and upwards until the remaining plug could be dynamited. Provision had been made for the accommodation of the plug debris and the operation was completely successful. This permitted the water level to be lowered by some 38 m. Further pumping allowed a permanent opening to be installed which is now protected by a 20 cm. grille with a surface area of 30 sq. m. and with bars spaced at 20 cm. It is interesting to note that while La Veyradère, Gage and La Palisse reservoirs are designed for use at a normal level of 1,011 m., 1,010 m., and 1,010 m. respectively, the Lac d'Issarlès must not be filled above 1,003 m. This storage lake is drained towards the Montpezat power station via the Gage and La Palisse dams. A close control of the sluice gates is therefore essential, the flow along the tunnels taking

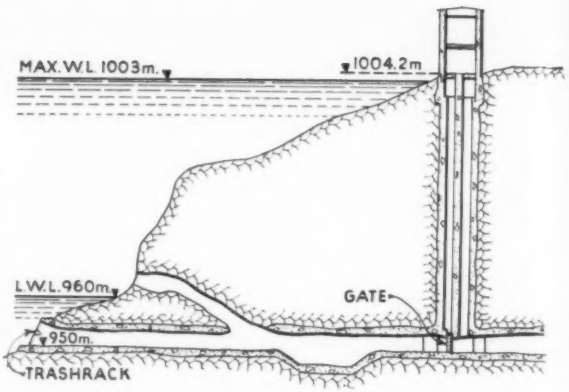


Fig. 19. Diagram illustrating method adopted for penetrating floor of lake

Fig. 20. View of the Lac d'Issarlès intake

place in either direction as desired.

Over 20 km. of tunnelling are associated with the Montpezat project and most of this was driven from a jumbo trolley on which five hammer drills were mounted. It may be mentioned here that an earlier project to pass the tunnel through the Cevennes was not undertaken because of a shatter belt associated with the ancient volcanic explosion vents. The path actually followed was shown to be fully justified by the smooth and uneventful progress of the tunnels. These were driven entirely in granite and no basalts were met with although a very damp cracked area which was traversed had to be supported by Toussaint frames erected every 0·75 m.

Acknowledgments

The writer is very happy to acknowledge his indebtedness to Electricité de France for permission to visit the Montpezat area and to publish this description. The photographs accompanying this article were taken and supplied by H. Baranger, Paris, except Fig. 7, which was supplied by The Oerlikon Engineering Company, Zurich.

Book Reviews

Les Barrages en Voûte Mince. Jean Lombardi. F. Rouge and Co. Ltd., Lausanne, Switzerland. 160 pp., 58 ff. Price 28·70 fr.

A recent paper by Prof. D. N. Allan and Prof. A. J. S. Pippard[1] on the experimental and mathematical analysis of arch dams, submitted to the Institution of Civil Engineers has caused the fundamentals of arch-dam calculation to be widely discussed in this country. The two authors start by writing the basic equations for the equilibrium of a small volume element of the dam. These equations consider the normal forces and all the shear forces on the six faces of the element and correlate them to the strains. Then these equations, which could not be integrated, are solved by relaxation, using the method of Prof. Southwell. The calculation proceeds step by step in three directions and the solution must satisfy all boundary conditions.

During the discussion of the paper it was stated that the solution submitted was the "mathematician's dam" to which any future approximate solution or model tests could be referred for comparison. This "mathematician's dam" could in future replace the tedious "trial-load" analysis for the complete stress function equations. Approximate methods have still to be found giving the best possible agreement with the "mathematician's dam" with a reasonable amount of calculation. The methods used for solving the "mathematician's dam" give no direct indication of how to develop these approximate methods.

The development of one such approximate method is the subject of the publication by M. Jean Lombardi. The author visualises an arch dam as an elastic shell for which the general equations of Love[7] are given. These equations cannot be integrated. The author analyses each term of these equations and by carefully selecting the terms of lesser importance which can be dropped brings the equation to a form which allows direct integration. He then proceeds to compare the solution with approximate methods derived from the American trial-load method. A full discussion, including detailed calculations follows.

In order to do full justice to this notable book some preliminary remarks are indispensable. With few exceptions the cumbersome trial-load analysis as developed by the American Bureau of Reclamation has never been popular in Europe. Italian engineers prefer to consider a dam consisting of a number of superimposed free arches. More recently they have been concentrating on model tests and direct measurements on existing dams (Oberti, Tonini). French engineers also rely on similar methods (Bourgin) with the exception of Coyne who developed the method of "plunging arches." The Swiss have systematically endeavoured to develop a method based on the papers by Noetzli (U.S.A.), Q. Ritter (Germany) and Stucky (Switzerland)[2] (which ultimately led to the development of the trial-load analysis in the U.S.A.). These papers consider any arch dam as composed of a system of horizontal arches and a system of vertical cantilevers. The deflections of both systems at the points of intersection must be identical, a condition which necessitates the hydrostatic load being divided between arches and cantilevers so that the deformations are equal. American practice consists in reaching this division of the hydrostatic load by a lengthy trial-and-error method. The Swiss solve directly the system of equations expressing the equality of the elastic deformations.

Prof. M. Ritter[3] gave a method reducing the whole problem to the solution of n linear equations with n unknown quantities which are the loads on the arches at the n points of intersection. The main effort of Ritter was to linearise the equations and to include in them the elastic deflection of the abutments. (The alternative method used by Pippard and Allan for representing the elasticity of the abutments is the so-called "artifice of Prof. Vogt"[6] which consists in imagining an ideal state with the base of the dam rigidly fixed at some finite depth, below the true, physical foundation level.) In connection with his studies on the Rossens dam, Ritter showed the fundamental importance of including the elasticity of the abutments in the equations for final dam design.

Two former students of Ritter contributed to the elucidation of some points of an arch-dam theory. Hofacker[4] produced the general stress and strain equations for a thick free arch rigidly built in at its ends, using an integration method which later on was to inspire Jean Lombardi in his own work. Bosshard[5] developed further on the method of Ritter.

The most important achievement of Lombardi is to include in the analysis the torsion of the dam, using a system of equations similar to those proposed by Ritter. He then compares this solution: (a) to the solution neglecting torsion; (b) to the direct integration of the equations of the thin shells.

Chapter I is a general introduction to the problem of arch-dam calculation.

Chapter II is devoted to the differential equations of Love[7], which are generalised to the case of varying shell thickness. The prerequisites for the application of the method is the existence of a clearly defined medium surface and thickness not exceeding one-fifth of the radius. In addition it is assumed that the hydraulic load is a volume force applied to the material of the dam through the action of the interstitial water pressure[10], so that the external stresses on both the downstream and the upstream face of the dam are zero.

Finally, as usual in the theory of shells, but not of arches, the radial shear forces are neglected. Lombardi always reintroduces these forces in his analysis by considering the general equations of equilibrium of forces. His basic idea is to neglect some terms in the strain equations provided they are small but no forces are neglected and all of them must be in equilibrium, with no alteration being brought to the general equation of forces.

The author's next step is to reduce the general equations of Love to the simplified equations of a cylinder with constant radius, but these are too complicated for direct integration.

Simplified equations have been given in 1934 by Flügge[8] and these are adopted as a first approximation. Flügge's equation compares with Love's more general equations by suppressing some terms of higher order. Lombardi proceeds simplifying the equations of Flügge by neglecting all the terms depending on Poisson's ratio (which is anyhow small for concrete) and by assuming that the thickness h of the dam is small as compared to the radius r. If $h/r = 1/5$ then

$h/12r^2 < 1/300$ and several terms containing this ratio can be suppressed. A last assumption consists in neglecting vertical dam deflections. To illustrate his points the author applies the simplified equations (a) to an independent arch, (b) to the trial-load method for which the basic equations are then developed.

Chapter III is devoted to the integration problem. A general analytical solution is, of course, out of the question but an approximate method is recommended. It consists in representing the "solution" by a finite series of suitable functions. The solution must satisfy the boundary conditions given by the hydrostatic water pressure. The method is developed in such a manner that the residual errors on the external load distribution conform with the Gaussian weighted least squares principle. The principle of the method is then fully explained by developing the relevant formulae for triangular and parabolic profiles. A parabolic profile is then fully calculated in Chapter V, on numerical examples (Fig. 37 shows the degree of approximation obtained by this direct integration).

Chapter IV deals at full length with the torsion problem. The analysis of Flügge's general equations show that the terms representing the shear force responsible for the torsion can be easily retained. The author then shows how the trial-load approach can be used for calculating a dam either including torsion or neglecting it. A detailed numerical example is worked out in chapter V. The various operations to be performed for this calculation are explained in chapter IV for the case of one simple vertical cantilever and for the case of several such cantilevers.

Chapter V deals with numerical applications.

The first example solved by the author is the thin built-in free arch. The results of four calculations are compared: (a) The result with the direct integration method by Hofacker, (b) the results when using the thin-shell equations for a two dimensional system, (c) the same calculation including the shear forces in a radial direction, (d) the calculations using the Theory of Navier on the linear stress distribution. The results are pretty close together. (It is interesting to note here that Hofacker's equations for a two-dimensional problem, page 17 of his thesis, are similar to the equations of Allan- Pippard for a three-dimensional system but that the equations of Flügge-Lombardi cannot be reduced to the same pattern, which made comparison by means of numerical results the more interesting.)

In this same paragraph the author studies the effect of the so-called "artifice of Vogt" for the abutments of a thin arch. The numerical example he gives underlines some difficult points involved. There are reasons for preferring the method of M. Ritter which allows the displacements of the abutments to be correctly considered in arch-dam calculations, without introducing the artifice of Vogt.

The other numerical examples concern the trial-load method compared with the direct-integration method with series of functions, as already mentioned when summarising chapters III and IV. Comparative calculations with and without torsion show that towards the middle of the dam the effect of this factor tends to transfer part of the load to the foundation of the cantilever, whereas at the sides it causes a larger part of the pressure to be taken by the arches. (See also conclusions, chapter VI, p. 131.)

This method has already been used by Lardy and Gicot for the Lienne Dam[9]. The principal stress diagrams published on p. 125 by the author also show the typical inclined stresses towards the arch abutments, as shown by the calculations of Allan and Pippard and by many model tests. (The ordinary methods of calculating the dam by considering horizontal "sliced" arches show the principal stresses to be on the contrary horizontal and vertical.)

The end of this chapter is devoted to the direct-integration method with finite series. Accuracy is obtained for the central part of the dam, but the errors increase towards the sides.

The thesis of M. Jean Lombardi is a major contribution to the most difficult problem of arch-dam calculation. It is of considerable help to those who value a better understanding of the strains and stresses developing in arch dams. By introducing torsion in the calculation of arch dams the author has considerably increased the value of the trial-load calculation—if this denomination can still be used for a method which replaces the "trial" by the direct calculation of a matrix. The interest of the thesis is enhanced by comparing its results with the findings of Allan and Pippard, Lardy and Gicot and to the methods of Hofacker and M. Ritter.

The book is indispensable to all dam designers and will most probably be considered as a classic in this domain.

C. JAEGER.

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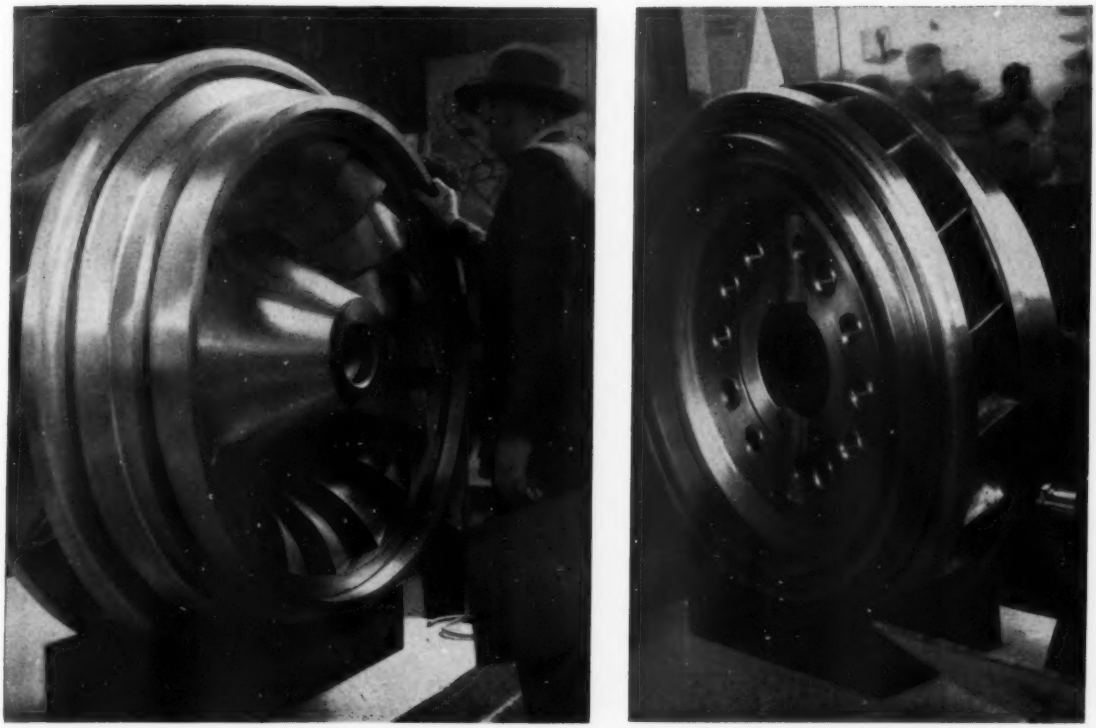
City and Guilds Broadsheet. The City and Guilds of London Institute, which for many years has been so closely identified with technical education, has commenced the publication of a Broadsheet to provide a regular flow of information concerning the Institute's activities. Issues will be published in February, April, June, October and December in each year. In recent years, in direct response to the demands of industry, there has been a tremendous increase in the Institute's activities, in the amount of development work undertaken and in the number of candidates entered for its examinations. In 1955, over 100,000 candidates entered for the City and Guilds examinations at centres throughout the United Kingdom and in thirty countries overseas.

Engineering Fluid Mechanics. By Charles Jaeger.

This, the English edition of Dr. Jaeger's book "Technische Hydraulik" is to be published by Blackie & Son Limited, 17 Stanhope Street, Glasgow, C.4, on June 14. We hope to publish a review of this book in an early issue.

World's Highest-Head Francis Runner



Front and rear views of one of the Fionnay Francis runners on the Escher-Wyss stand at the recent Basle Fair

In the use of Francis turbines for high heads certain limits are encountered. In certain circumstances the maximum admissible outlet velocity of the water from the runner is a limiting factor, and a further consideration is the highest permissible speed in view of the tensile strength of the generator rotor. In certain cases the question of wear must also be carefully taken into account.

The danger of cavitation need not be referred to in detail as it is practically always possible to eliminate damage from this cause by correct choice of the elevation of the turbine and by employing suitable materials. On the other hand, to combat erosion it is necessary to ensure that the water is as free as possible from sand, chiefly on account of the labyrinth rings and protecting rings. In Francis installations working in conjunction with large artificial lakes the danger of sand being brought in is practically eliminated, so that reaction turbines can be adopted without hesitation also for relatively high heads. As an example of the performance of a high-pressure Francis turbine operating under normal hydraulic conditions reference may be made to the set supplied by Escher Wyss to the Bitto plant in Italy, which develops 14,620 h.p. under a net head of 374 m. and has been in practically uninterrupted service since the beginning of 1944. When carrying out an overhaul after 33,000 hours of operation the runner blade and labyrinths were found to be in perfect condition.

On the basis of such satisfactory experience the firm of Escher Wyss also received a contract from the Forces Motrices du Mauvoisin, Sion (Valais), for three machines for the underground power station of Fionnay in the Val des Bagnes. These units will operate under a maximum head of $H = 455$ m., $Q = 11{,}500$ lit./sec., $N = 62{,}800$ h.p., $n = 750$ r.p.m. The great adaptability of these spiral turbines should be particularly mentioned. On account of the large fluctuations in level of the artificial lake the turbines have to operate reliably under heads varying from 455 m. to 284 m., when 35,300 h.p. is still developed. The turbine runner is made of stainless cast steel and subject to a minimum back-pressure of 3·5 m. The runaway speed of the turbine is 1,400 r.p.m.

This installation will operate under the highest head for which Francis turbines of such output have hitherto been adopted. Erection of two sets has been completed, which will be taken into operation very shortly. The third set is at present being completed in the works.

Escher Wyss are at present also manufacturing two vertical Francis turbines for the Safien-Platz installation of the Zervreila Power Supply Co., Vals (Grisons), for: Maximum head $H = 422$ m., $Q = 11{\cdot}75$ cu. m./sec., $N = 58{,}850$ h.p., $n = 750$ r.p.m. In principle these turbines are of the same design as the Fionnay machines, and they will develop 52,700 h.p. each under the minimum head of 395 m.

Vancouver Island Cable Shipped

Fig. 1. The whole of the cable required for the contract stored in the coiling-down shed. Four stacks are visible, the fifth being hidden because of the height of the fourth stack

The decision taken about four years ago by British Columbia Electric Co. Ltd. to lay a high-voltage power cable across the Strait of Georgia from the mainland to Vancouver Island was a courageous one, as long-distance submarine power transmission was relatively untried. Nevertheless it was intrinsically sound, for it made the abundant hydro-power of the mainland available to the island, and avoided the necessity to build two thermal stations. Equal courage was shown by British Insulated (Submarine Cables) Limited, who in being awarded a $3 million contract two years ago undertook a large programme of development work to fulfil their obligations. Special machinery had to be designed, and special buildings erected, to manufacture, store and handle the cable; yet the cable has been manufactured ahead of schedule, and when we visited the BICC Trafford Park works last month, was in process of being loaded on to the cable-laying ship *Ocean Layer*.

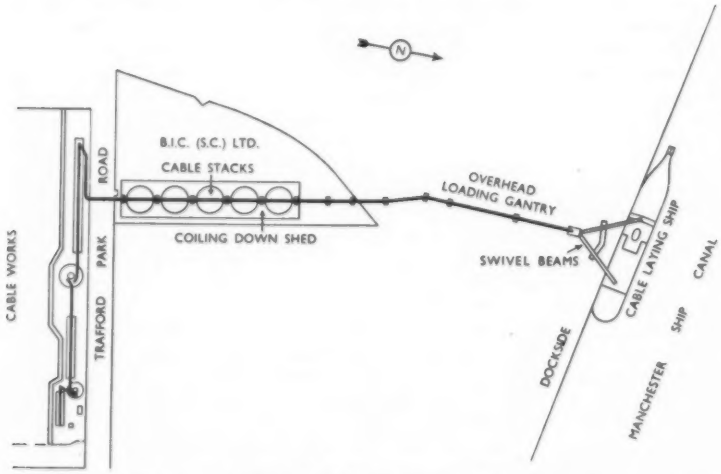


Fig. 2. Diagram showing cable storage and loading arrangements

The cable is of the single-core gas-pressure type, four inches in overall diameter and weighing 50 lb. per yard. Three of these cables will form a three-phase circuit and a fourth will act as a spare, and the link will be capable of transmitting 100 MW at 138 kV.

An unusual and probably unique feature is that the four 16 mile lengths designed to cross the main Strait have been manufactured

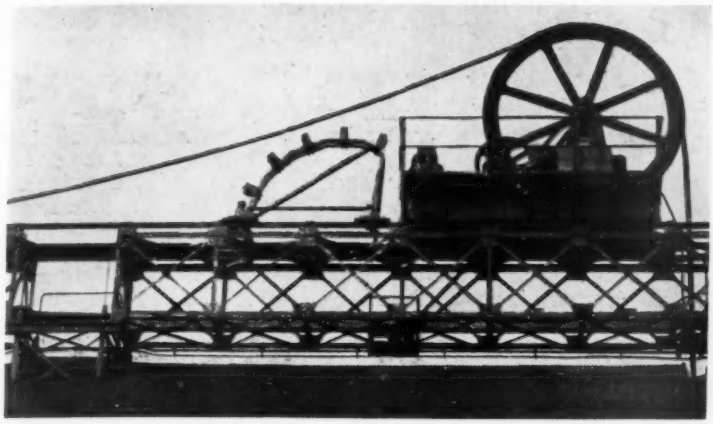


Fig. 3. Part of the power-operated gantry system showing the cable passing over a sheave-winch into one of the bays in the coiling-down shed

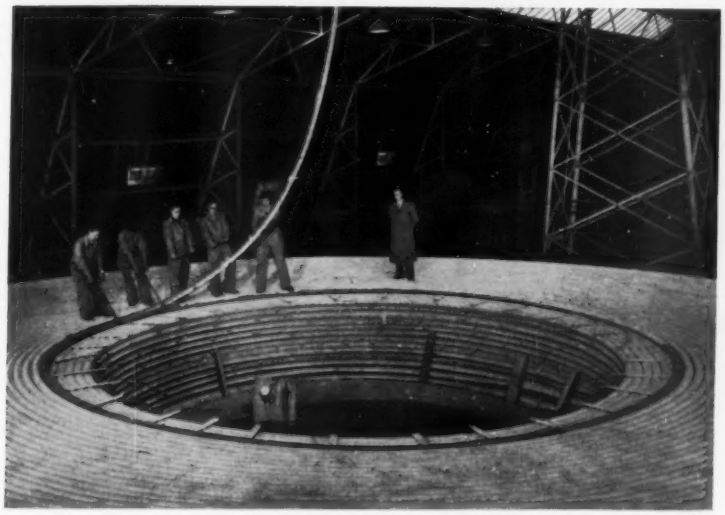


Fig. 4. One of the cable stacks containing a 16-mile length of cable

entirely without joint (Fig. 4). This is no mean engineering achievement, and it avoids the use of underwater joints. Four 3½ mile jointless lengths have also been made for an inter-island connection.

Clearly, cables many miles in length and weighing hundreds of tons cannot be put on drums, and special loading and transport arrangements have therefore been designed. From the factory to the dockside a purpose designed power-operated gantry system has been constructed. This crosses the Trafford Park Road at a height of 45 ft. and extends for a total length of 1,100 ft. to the quay where the gantry proper terminates on a tower 120 ft. from the edge of the quayside. Thence two swivel beams, which can be swung through a small arc on rails mounted on a cross gantry, provide twin cable-runs directly above the holds of the cable ship. The general arrangement can be seen in Fig. 2.

For the storage of the cable between manufacture and loading a steel-cladded coiling-down shed has been constructed directly beneath a section of the gantry. This shed is 350 ft. long, 74 ft. wide and has a height of 43 ft. 6 in. to the apex; this permits an unobstructed floor area of approximately 20,000 sq. ft. for cable storage and allows five cable stacks each with a diameter of up to 60 ft.

On the gantry above the coiling-down shed a pair of light rails forms a track for two sheave-winches, which are mounted on skids and can be moved into position over any of the five coiling bays (Fig. 3). When the cable-laying ship is alongside, a caterpillar winch mounted on the gantry pulls a cable from its coil in the shed over a quadrant at gantry level and along the gantry to the winch, and then pushes it along one of the swivel beams so that it can be lowered and coiled into the ship's hold directly below. Telephone communication is maintained between quayside, winch positions and each coiling bay in the shed during loading and coiling operations.

Recently, the nine submarine cables were stacked in huge coils on the floor of the shed, presenting the unique sight of approximately £1,000,000 worth of cable in one place at one time (Fig. 1) and weighing over 3,800 tons.

The 4,600 ton *Ocean Layer* is the second largest cable-laying ship in the world and belongs to Submarine Cables Limited. She is the first British ship to be fitted with a Pleuger active rudder—a device consisting of an auxiliary propeller housed in the pear-shaped rudder blade and designed to increase the vessel's manoeuvrability—an essential feature in cable - laying operations. The *Ocean Layer* has a service speed of 11 knots. Her modern cable-handling gear and testing equipment, incorporating the latest electronic control devices as well as the most up-to-date navigational aids, make her the best equipped cable ship in the world.

When loading is complete this ship will sail for Vancouver via the Panama Canal, taking some 40 days for the voyage. The final stage will be cable-laying operations in Georgia Strait, Vancouver, followed by termination at appropriate shore sites and finally testing the complete installation. This pioneering submarine power cable link is due to be in operation during September 1956.

It is not without interest to recall that the BICC Group collaborated with the British Electricity Authority (now C.E.A.) in 1953 in full-scale trials for the England-to-France Cross-Channel cable project, and that, as we recorded recently, the New Zealand Government awarded BICC an investigation contract to examine and report on the possibility of a submarine power cable connection between the North and South Islands across Cook Strait.

Turbine for Borehole Drilling

Water turbines are used for a number of specialised purposes—for instance in the chemical industry—but a turbine for a most unusual application has been developed by Ets. Neyrpic, Grenoble, this being a machine for borehole drilling. This turbine is designed to be lowered down the borehole and incorporates the rotating shaft carrying the drilling bit. It derives its power from the water or the mud that is needed in any case to flush out the borehole, the only major change-over from rotary drilling being that the capacity of the pumps may have to be increased. One of these turbo-drills has recently been tested against a rotary drill in a 650 m. borehole at St. Bauzille de Montmel, and although as a responsible journal we do not like the use of superlatives, the increase in the rate of advance can only be described as phenomenal.

The reasons for such a striking difference in performance become obvious when the fundamentals of borehole drilling are considered. It has long been known that the rate of penetration increases roughly in direct proportion to the load on the drilling bit, the speed of rotation, and the discharge of circulating

Fig. 1. A 10 in. Neyrpic borehole turbine with two containers

fluid. Over the past years it has been possible to step up the rate of circulation but attempts to increase the drilling torque simultaneously with the rotation speed have been limited in conventional rotary practice by the string of drill pipe extending from the rotary table at the surface to the bit. The horsepower that can be transmitted in this system by the drill pipe rarely exceeds two figures, whereas it has been established that the best results are obtainable when the horse-power is measured in hundreds.

With a turbine located near the bottom of the borehole and directly connected to the bit this limitation can be overcome. Further, by increasing the mud volume, the speed of rotation of the turbine and its torque—in other words the weight on the bit—are increased simultaneously. In fact, the turbine output increases as the cube of the discharge and the rate of advance as the fourth power. Thus, by doubling the discharge the rate of advance can in some cases be increased sixteenfold.

The turbine consists of a tubular body, a central shaft carrying the drilling bit and a series of turbine elements, the stationary vanes being integral with the tubular body and the impellers with the shaft. Shaft bearings and a thrust bearing complete the assembly. One of these turbines, with two containers, is shown in Fig. 1. A 10 in. turbine for boreholes from 11 to 18 in. in diameter is already available, a $7\frac{3}{4}$ in. turbine for

Fig. 2. Borehole turbine in service

$8\frac{1}{2}$ to $9\frac{7}{8}$ in. boreholes, and a 5 in. turbine intended mainly for geological prospecting are in course of manufacture, and a 4 in. turbine will later complete the series. A turbine armed with its three-cone rock bit is shown in Fig. 2.

In the tests referred to earlier, a rotary drill and a turbine drill were used alternately in a $12\frac{1}{4}$ in. borehole from 264·25 m. to 651·59 m., the strata ranging from marly limestone to siliceous limestone. The slowest rate of advance with the rotary drill was 0·79 m. per hour and the fastest 2·20 m. per hour. With the turbine the rate of advance ranged from 6·63 to 15·40 m. per hour. Later, speeds of over 30 m. per hour have been attained. With the turbine, rock-bit life was actually increased by an average of 33 per cent.

World's Largest Reversible Pump-Turbine

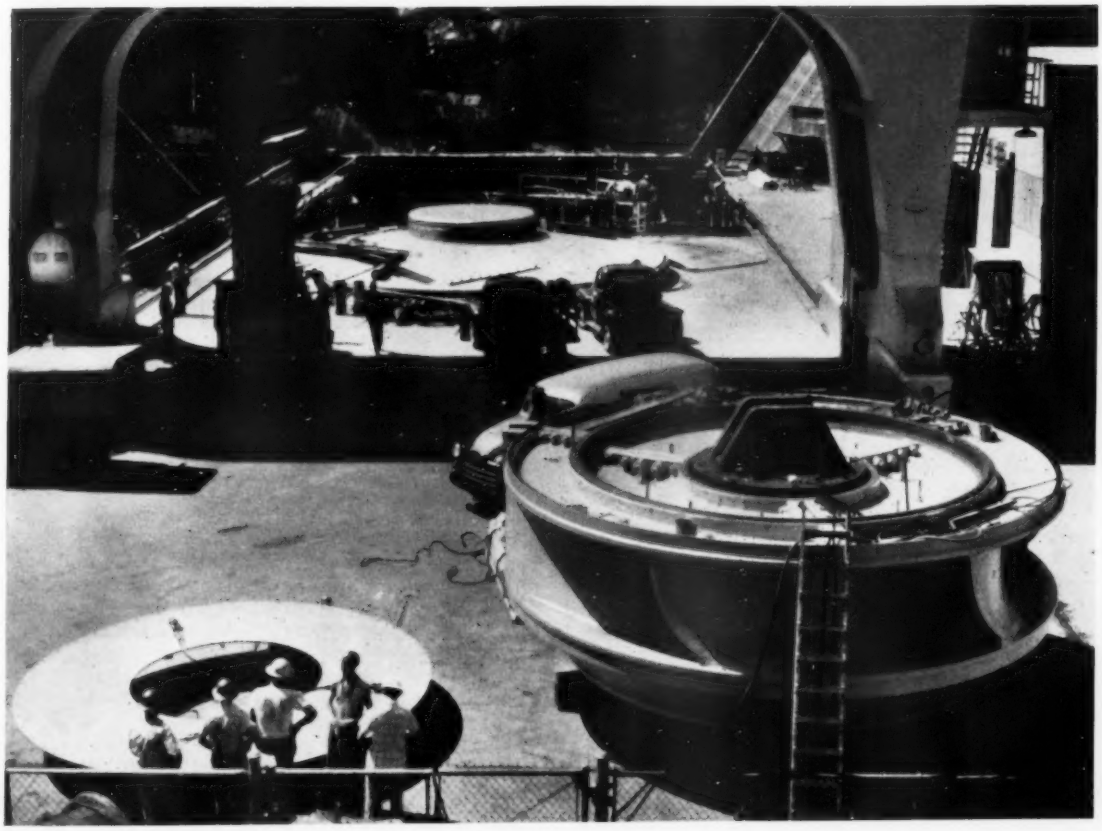


Fig. 1. Assembled three-piece pump-turbine runner on the deck of the outdoor power house at Hiwassee dam

What is believed to be the world's largest reversible pump-turbine unit, designed and built by Allis-Chalmers Manufacturing Company for TVA's Hiwassee dam, is the heart of a plan for storing large blocks of power. It was scheduled for full operation early in May, and is stated to be the first installation in the western hemisphere of a reversible pump-turbine for the initial purpose of helping to level system load curves.

Electrically, this dual-purpose machine is rated 70,000 kVA as a hydraulic turbine-generator and 102,000 h.p. as a pump-driving motor—the world's largest by more than 20,000 h.p. Hydraulically, it is designed to generate 80,000 h.p. under 190 ft. head—to pump 3,900 cusecs against 205 ft. head. Rotation is clockwise for generating, counter-clockwise for pumping.

In pumped-storage systems, the reversible pump-turbine unit can generate electric power to help meet peak day-time demands, drawing on water stored for that purpose. In off-peak night-time or week-end hours, the supply of available electric power exceeds the normal demand. The machine can then be motorised to pump water back into the storage reservoir. It is, in effect, the means by which surplus electrical energy can be converted to water power, stored and reconverted when needed to fill electric power requirements. With the large reversible pump-turbine units, approximately three kilowatts can be generated for every four kilowatts used for pumping. The Hiwassee unit will assure maximum plant capacity during seasonal peak-load periods when water level is normally low.

According to Allis-Chalmers, the new machine boasts many record breakers. In addition to being the world's largest pump-turbine, its 266 in. Francis-type runner is larger in diameter than any other. The electrical component, rated at 102,000 h.p. as a motor, has no equal. If the full pumping capability of the unit were utilised over a 24-hour period at lower than rated head, it would lift more than three and a quarter billion gallons of water—three times the average daily requirement of New York City.

Significantly, although it is a relatively new concept, components of the reversible pump-turbine are little different from those already incorporated in many

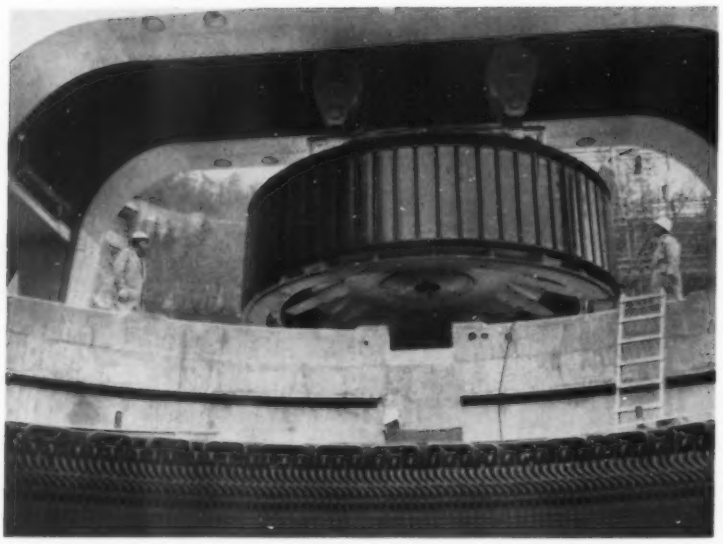


Fig. 2. Motor rotor suspended on the portal crane at Hiwassee dam. Part of the stator is visible in the foreground

vertical hydro-electric machines. The pivoted shoe-type thrust bearing, for example, is inherently suited for reversible operation. That for the Hiwassee machine supports a total of 1,365,000 lb.

To reduce breakaway torque in starting, both for motoring and generating, thrust bearings for reversible units are fitted for high-pressure lubrication. The high-pressure system operates in the starting cycle, establishing a film of oil between thrust bearing surfaces so effectively that one man can readily start the Hiwassee machine rotating by pushing against an arm of the rotor spider. This system is in use on very large hydro-generator installations, as well.

The pump-turbine runner is similar to the Francis-type turbine runner in design, but is modified for high efficiency as pump and turbine. Hydraulic control of the Hiwassee unit is by means of movable wicket gates.

Variations between the unit's electrical characteristics and those of a typical hydraulic turbine-generator are chiefly due to its dual purpose as generator and motor. Ratings are 102,000 h.p., 95 per cent. power factor, 80°C. rise, 13,500 V, 135·9 r.p.m. as a motor; 59,500/68,425 kW, 70,000/80,500 kVA, 60/80°C. rise, 85 per cent. power factor, 105·9 r.p.m. as a generator.

A ring of 20 adjustable wicket gates controls the flow of water to the unit's impeller runner for power generation, and likewise regulates the flow of pumped water for greatest efficiency. When starting as a pump, the wicket gates are closed and a compressed air blow-down system dewaters the runner. This reduces motor starting torque requirements and eliminates system disturbances. Reduced-voltage starting limits current inrush below normal load. The motor is then started and brought up to speed. Release of air pressure allows the water level to rise in the impeller, the wicket gates slowly open to the proper setting and water flows up the penstock into the storage reservoir. Much the same sequence, in reverse, is followed at the end of the pumping cycle. For power generation, the unit is started in the same manner as a conventional hydraulic-turbine unit.

Shipping a unit as large as that at Hiwassee is a major problem. The 266 in. turbine runner, for example, was built and shipped in three sections, and bolted together at site. By contrast, the largest runner of this type that could be handled as a single shipment would be rated 48,000 h.p. compared with 80,000 h.p. for the installed runner.

The generator-motor stator was also built and shipped in three sections, partially wound at the factory, and finish-wound on the job. The rotor spider was too large in diameter to meet shipping limits and it also was shipped in sections and bolted together at the dam site. Rim laminations and field poles were assembled on the spider just prior to installation. Finished rotor weight was over 300 tons.

The concept of pumped storage for hydraulic power purposes is not new. However, the reversible unit, which combines pump and turbine, generator and motor, into a single integrated machine, is a recent development. Another unit of this type, also built by Allis-Chalmers, is operating in the Flatiron Power and Pumping Plant in Colorado.

Course on Hydrodynamic Stability

"Hydrodynamic Stability," a two-week special summer programme on the problems of instability in laminar flow and turbulence, will be given at the Massachusetts Institute of Technology from July 16 to July 27. According to Professor Ernest H. Huntress, Director of the M.I.T. Summer Session, who announced the plans, this special summer programme will consist of an organised presentation of basic knowledge of instability of laminar flow and turbulence, and lectures on the application of these principles to more specialised fields. Material covered in the programme includes: the theory of hydrodynamic instability; transition from laminar flow to turbulence; statistical theory of turbulence and related topics in engineering, meteorology, and acoustics, presented by specialists in the various fields.

Dr. Chia-Chiao Lin, Professor of Mathematics at M.I.T., will direct the programme. Members of the M.I.T. Faculty assisting Dr. Lin will be Professor Arthur T. Ippen, Director of the M.I.T. Hydrodynamics Laboratory; Dr. Victor P. Starr, Associate Professor of Meteorology; and Dr. Uno K. Ingard, Assistant Professor of Physics. Professor S. Corrsin, Chairman of the Department of Mechanical Engineering, John Hopkins University, Baltimore, Maryland, will also lecture.

Full details and application blanks may be obtained from the Summer Session Office, Room 7-103, Massachusetts Institute of Technology, Cambridge 39.

Abstracts from the World Technical Press

Snake River Development

Pacific Northwest Power Company has asked the Federal Power Commission for permission to develop two sites on the middle Snake River between Oregon and Idaho. The Mountain Sheep Project calls for a 255 ft. high concrete gravity dam with a 1,700 acre reservoir which, at a top level of 1,113 ft. above sea level, would provide a gross head of 163 ft.; the dam-toe power house would have a three-unit initial capacity of 330 MW, to be raised later to 432 MW by an additional unit. The second project would include a 534 ft. high concrete arch dam at Pleasant Valley, with a reservoir at 1,490 ft. above sea level, and a 377 ft. gross head for power production; two power houses downstream of the dam, one on the Oregon, the other on the Idaho side, would have an initial capacity of 850 MW from five units, to rise to 1,014 MW by the addition of a sixth unit. The generators would be of the semi-outdoor type and would be rated at 144 MW, with a capacity of 170 MW at full gate opening. (*Engineering News-Record*, Vol. 155, No. 11, Sept. 15, 1955, p. 28.)

Solar Energy

An outline is given of the latest research and experiments on the harnessing of solar energy to power generation. Among the latest solutions suggested, the most interesting appears to be a system of heat absorbers which consists of blackened metal plates, and heats a substantial quantity of water to about 70° C. The water is then circulated in a heat exchanger in counterflow to another low-ebullition-point fluid, generally freon. The freon vapours are superheated by a system of parabolic mirrors, and made to expand in a small high-speed reciprocating engine; after expansion, the vapours pass through a condenser, and the working cycle starts afresh. This method is still at the experimental stage, and its economic suitability has still to be proved. The article ends with a brief account of the experiments made by the General Electric Company and the Bell Telephone Company in U.S.A. with a view to transforming radiant energy directly into electric energy. (*Quaderni di Studie e Notizie*, Vol. 11, No. 203, 16.9.1955, p. 666, 3 pp.)

The Aare River as a Source of Energy

Intended as an introduction to an article to be published at a later date on the Aare power stations, this exhaustive survey deals with the wide possibilities offered by the river to hydro-electric development. Following catastrophic floods, which particularly hit the Thun district and finally transformed the region between the Jura Lakes and the township of Büren into a vast swamp, extensive work towards the regulation of the Jura waters was carried out between 1867 and 1891, and since 1878 the Aare has flowed into the Bielersee. Later regulation stages involved the setting up of weirs in the Nidau-Büren canal and brought about considerable improvements. However, the latest great floods of 1944 and 1950 clearly established that, owing to extensive silting, the cross-sections of the canals connecting the Jura Lakes are much too small. In fact, in spite of an aggregate area of 280 sq. km., the three Jura Lakes are today still unable to store the additional discharge of the Aare, Saane and other rivers at high-water periods. A reconstruction of the Nidau-Büren canal and a thorough regulation of the stretch of the Aare downstream of Solothurn is fairly urgent. The final solution aimed at can be supplied by the planned Transhelvetic canal which would lead from the Lake of Geneva through the Entreroches canal and the Neuchatel and Biel Lakes to the Aare, thus setting up a Swiss Rhone-Rhine navigable waterway. Freight traffic would again sail on the Aare, and a division of the head available into appropriate stages would provide possibilities for the construction of hydro-electric installations. The survey also discusses the size of run-of-river plans on the Aare, and further paragraphs are devoted to average and specific precipitations in the region involved, as well as to flood discharge. (P. Moser, *Technische Rundschau*, Vol. 47, 16.9.1955, No. 39, p. 27, 3 pp., 8 ff.)

Val Bregaglia Development

Worked out by the Hydro-electric Division of the Zurich Corporation for the development of the Val Bregaglia (Grisons) the project described in this article comprises two stages: (1) the Albigna works, with the Albigna reservoir, the Val Forno and Val Maroz diversions, and the Löbbia power station; (2) The Castasegna power house, which utilises in a single stage the head available between Löbbia and the Italian border. The Albigna gravity dam, 755 m. in crest length by 110 m. in maximum height, creates a reservoir 60 million cu. m. in capacity; owing to the configuration of the flanks of the valley, the axis of the dam is broken at two points, both wings receding southwards. The Albigna pressure tunnel, 4·6 km. in length, with a diameter varying between 2·5 m. in the concrete-lined, and 3 m. in the unlined section, connects downstream of the underground surge tank with a 1,100 m. long steel-lined pressure shaft which in its turn leads to a 750 m. penstock 1,600/1,400 mm. in diameter. The two diversions comprise each an intake, complete with weir, pressure tunnel, surge tank and penstock. The Löbbia power station, on the left bank of the balancing reservoir, houses three generating sets: Nos. 1 and 2, consisting each of a 38,000 kVA horizontal generator driven at 500 r.p.m. by two 22,000 h.p. Pelton wheels, and No. 3, which consists of a 9,000 kVA generator-motor driven by a 10,000 h.p. Pelton wheel, and of a storage pump designed for a capacity of 3 to 4 cu. m. per sec. and a lift of 86 to 191 m. In winter, Nos. 1 and 2 sets utilise normally only the water from the Albigna reservoir, while No. 3 is fed by the Forno and Maroz diversions, the pump being disconnected. In summer, No. 2 is operated by the Forno and Maroz intakes, and No. 3 set acts either as a generating set fed from the same intakes, or as a storage pumping set actuated at discretion hydraulically or electrically, the water being pumped into the Albigna reservoir; No. 1 set, on the other hand, serves as a standby for generating peak energy from the Albigna reservoir. The outdoor 225 kV substation stands north of the power house. The Castasegna works consist of a 11·3 km. pressure tunnel, a surge

tank and a steel-lined pressure shaft together with the gate chamber which operates either automatically or by remote control from the underground power house. The head and capacity of the two stages being fairly similar, the two generating sets at Castasegna are identical with the Albigna main sets. An inclined shaft connects the underground power house with the outdoor 225 kV switchyard. Work on this important new venture of the Zurich Corporation is already in progress and is scheduled to last six or seven years; impounding at Albigna will be effected while the dam is in course of construction with a view to starting energy production in 1959. (Contributed by Electricity Works of the Zurich Corporation, *Bulletin de l'Association Suisse des Electriciens*, Vol. 46, No. 23, 12.11.1955, p. 1101, 6 pp., 3 ff., 1 table.)

Swiss Electricity Production

From the report of the Committee of the UCS (Union des Centrales Suisses d'Electricité = Association of Swiss Electricity Works) to its general meeting, held in Lucerne on October 1, 1955, we learn that the production of hydro-electric energy in Switzerland remained in 1954 slightly below the production of the previous year, 12,994 against 13,407 million kWh, owing to less favourable hydrological conditions. Thermal production and imports increased however from 58 and 486 million kWh to 186 and 1,197 million kWh respectively, so that the aggregate production available in 1954 shows an increase of 426 million kWh. Hydro-electric installations put into commission in 1954, inclusive of the Swiss share at Birsfelden, raised the average yearly production by 828·5 million kWh, a figure which will increase by 3,247·9 million kWh, once installations in progress at the end of 1954 are completed. In 1961/62 it is expected that the average hydro-electric production available, under normal hydrological conditions, will reach 20,750 million kWh. A length of 225·2 km. of high-voltage lines has been added to the Swiss network, and lines in course of erection at the end of the year, most of them 225 kV, represent a further 360 km. At the present moment, it is estimated that the ceiling of economical exploitation of Switzerland's hydro-electric resources is about 30,000 million kWh, and it is expected that this consumption, even with a moderate increase of the demand, will have been reached within 20 to 25 years. To resort to other possible sources of energy is therefore as urgent a problem in Switzerland as in other countries less favoured with hydro-electric resources, and an experimental nuclear reactor is to be built at an expense of about 20 million Sw.Fr. to which 45 Swiss electricity undertakings, united in the Société de Participation au Réacteur, are contributing five million Sw.Fr. (UCS Supplement to *Bulletin de l'Association Suisse des Electriciens*, Vol. 46 (1955), No. 18, 3.9.1955, p. 841, 14 pp., 3 ff.)

Welding Stresses Crack Penstocks

This article describes the procedure adopted for repairing three power penstocks at Garrison dam, which developed extensive cracking while being welded. The penstock-riser-surge-tank assembly is of gigantic proportions and had to be field erected. Welding of such large components under field conditions sets up tremendous stresses, and, in this instance, was complicated by the complex pattern of curvatures involved in the design. The result was cracking which, occasionally, occurred suddenly, while workmen were on the job, with a sharp noise that sounded like a cannon explosion. Some of the cracks in the heavy steel plate were nearly 3 ft. in length; the vicinity of the intersection of the diagonal reinforcing yokes, just above the centreline of the penstocks, was first affected. Stress relief by means of a cut-out about 9 ft. 6 in. by 11 ft. 8 in. in the area of the penstock and riser, subsequently annealed in a furnace and welded back in place, failed to halt the cracking, indicating the presence of excessive stresses everywhere. Upon the recommendation of Professor Bijlaard, Cornell University, the entire fabricated steel connection at the tee-shaped junction of the penstock and risers is now being encased in reinforced concrete, this encasement providing strength while the principal role of the steel plate penstock and risers is reduced to that of a liner plate against water leakage. Concrete reinforcement consists mainly of 2 in. diameter bars with welded splices. Although the design's shortcomings showed up in No. 1 unit, work on Nos. 2 and 3 units went on, because the component parts had already arrived at the dam site and were partially assembled. When constructing units 4 and 5 (the final two penstock-riser-surge-tank assemblies), the reinforcing yokes will probably be left off, and a more heavily reinforced concrete encasement used. In addition to the heavy cost of these remedial measures, estimated at $1·5 million, hydro-power production, scheduled to begin during the summer of 1955, will be delayed at least four months. (*Engineering News-Record*, Vol. 155, No. 18, Nov. 3, 1955, pp. 32/33, 2 ff.)

NOTE.—The above-mentioned journal also contains a survey of the progress of *St. Lawrence Construction after One Year*, p. 34, 5 pp., 5 ff.)

Dams on Delaware

Hydro development of 200 MW on Delaware River is proposed by Delaware River Development Corporation's new application to FPC for preliminary permit. Three plants are proposed: 150,000 h.p. at Tocks Island, N.Y.; 72,000 h.p. at Belvidere, N.J.; and 60,000 h.p. at Chestnut Hill, Pa. The plan could also provide water for domestic consumption. Another plan, motivated by growing need for domestic water, and to be submitted shortly to the New Jersey Legislature, is to tap the upper Delaware and would include small pumped-storage installations. (*Electrical World*, Vol 145, No. 3, Jan. 16, 1956, p. 7.)

Pleasant Valley Dam Model Studies

The physical and hydraulic dimensions of this huge structure are being checked on a 1 : 50 scale model by the Test Unit of Washington State College, Pullman. Besides its great height of 534 ft., this proposed installation on the middle Snake River will have the world's largest power equipment of its type: six 170,000 kW generators 49 ft. in diameter, and six 233,500 h.p. turbines with the largest waterwheels ever built in one piece. Design and performance of such outstanding features as these will have had full model study before the prototype is constructed. Investigations are now under way to develop answers to hydraulic problems of water elevations, wave actions, velocities, pressures and the like. Actual conditions of overflow and operation are simulated on a vermiculite-concrete model of the dam and its downstream channel topography. The model of the dam is 10½ ft.

high and 25 ft. long, and the channel downstream extends over 60 ft. Two 4,500 g.p.m. pumps send flows up to 7,500 g.p.m. over the spillway of the model. (*Engineering News-Record*, Vol. 155, No. 24, Dec. 15, 1955, p. 68, 1 f.)

NOTE. Another article on Pleasant Valley dam studies appeared in *Electrical World*, Vol. 145, No. 1, Jan. 2, 1956, pp. 24/25, 4 ff.)

Feather River Project

California's proposed $1,600 million Feather River project is called feasible on both engineering and financial aspects in a report prepared by the Bechtel Corporation. In essence, the report makes no significant changes in the concept of the project; the main difference between Bechtel's recommendations and the programme previously advocated by the State Engineer affects Oroville dam, a concrete gravity structure which, with a volume of 14 million cu. yards and a height of 730 ft., exceeds Grand Coulee in size and Hoover in height. California sentiment now is for immediate construction of the huge dam to take advantage of the flood-control potential at the earliest possible date; Bechtel, on the other hand, favour a delay in starting construction work on the dam because there is enough water flowing into the Sacramento-San Joaquin River delta region to fulfil initial water demands of the project, and power demands of the Feather River aqueduct pumping plant do not make the 440,000 kW power plant at the dam necessary at the start. It is however probable that the Bechtel report was written before the late December California floods. From the financial aspect, neither Bechtel nor the state had considered federal participation possible in analysing the economic feasibility of the project. The Bechtel report now advocates federal participation, which would make the whole scheme even more attractive financially. Federal participation would, besides, justify construction of Oroville dam earlier than recommended in the report. (*Engineering News-Record*, Vol. 156, No. 3, 19.1.1956, p. 26.)

Water Power in Bulgaria

The following information of hydro-electric interest is given in an article dealing with water problems in Bulgaria. The country, with an area of no more than 110,000 sq. km., has an average yearly rainfall of about 660 mm.; underground water resources have not yet been adequately investigated, and are roughly estimated at 10,000 million cu. m., that is to say about double the utilisable volume of possible surface accumulation. The aggregate length of rivers and streams is about 21,000 km., with a yearly discharge into the sea of 13,000 to 14,000 million cu. m. With regard to hydro-electric development, fairly accurate investigations on economically utilisable resources indicate that with an installed capacity of 1·2 to 1·3 million kW, minimum production would be 4,000 to 5,000 million kWh, of which 75 per cent. would be contributed by regions comprised between 1,000 and 3,000 m. above sea level. In fact, most existing Bulgarian hydro-electric plants are set up in such regions, and operate as high-head developments. Conditions favourable to run-of-river developments are practically non-existent. Altogether, the country's main water problem consists in bringing power interests into harmony with irrigation and domestic requirements. Valley damming would appear to be the most rational solution, and the author suggests two alternatives, either single-dam developments devoted to power generation during irrigation off-periods only, or two-dam schemes with an upper dam attending to power production only, and a lower dam operating purely as an irrigation structure. The Arda and Vatsha cascade-type developments in the Rhodope mountains have proved very satisfactory, and their pattern is certainly the most advantageous where favourable topographic and geological conditions are available. Pending completion of geological and economic surveys, comparative estimates show that about 60 to 70 multipurpose large dams with an average impounding capacity of 80 to 150 million cu. m. would be required to utilise to the full the water resources available. In addition, a great number of small earthfill or rockfill dams set up in suitable lower regions and plains could create reservoirs of up to 2 million cu. m. in capacity for the irrigation of smaller areas. (Professor Dipl. Ing. Christophor Baydanoff, Sofia, *Wasserwirtschaft-Wassertechnik*, Vol. 5, No. 12, December 1955, pp. 385 to 387.)

Hydro Expansion in U.S.A.

The Pacific Power & Light Company recently announced a licence request for a 256,000 kW project on the Lewis River, north of Portland, Oregon, this April being scheduled for the construction start, and late 1958 for initial power generation. The same company also announced an application to the Federal Power Commission for permission to study another project still higher in the Lewis River watershed for a contemplated 74,000 kW. The immediate development, known as Swift Project, will include two power houses and a 2,000 ft. long earth and rockfill dam creating a 740,000 acre ft. reservoir. Power Plant No. 1, at the foot of the dam, will have three generators totalling 189,000 kW, and its 3½ miles long tailrace will feed Plant No. 2, where two generators are to put 67,500 kW on the line. Water will then flow into the Yale Reservoir. Swift dam will be 510 ft. high, over 2,100 ft. thick at its base, and will contain 16 million cu. yard of fill. The later development, named the Meadows project, would collect water from four Lewis River tributaries through a system of five dams and two power houses. (*Engineering News-Record*, Vol. 156, No. 3, 19.1.1956, p. 33.)

The Only Three Kaplans on the Missouri

At Gavin's Point dam—where Missouri River flow is to be re-regulated finally after use at Fort Randall, Oahe and Garrison dams upstream—the only three Kaplan turbines on the river will develop a total of 100,000 kW. All other generating units on the lower Missouri have Francis runners operating from medium heads. At Gavin's Point low head behind the dam (40 to 66 ft.) dictated the choice of Kaplan units; a second reason for using Kaplan runners in this instance is the function of Gavin's Point dam as a re-regulation structure. Surges as high as 5 ft. will be sent downstream from Fort Randall and must be ironed out by Gavin's Point to prevent further damage downstream. The Kaplan adjustable-blade runners will be able to adjust relatively close to such flow variations. Under full load at rated head, each Gavin's Point Kaplan turbine will pass 9,000 cusecs., that is to say, more water than absorbed by the Francis units at Fort Randall under maximum head. Yet these Kaplan units also will

adjust to operate efficiently under less than full load. Erection work at Gavin's Point is proceeding at such a pace that No. 1 Unit is expected to be on the line early next Autumn, with Nos. 2 and 3 to follow at four-month intervals. (*Engineering News-Record*, Vol. 156, No. 6, 9.2.1956, p. 51, 2 ff.)

Niagara Hydraulic Models

A comprehensive programme of model testing was carried out before the recent redevelopments at Niagara. The paper outlines the major problems encountered, their solution, and the economic and technical advantages of the model analysis. On the whole, these extensive tests resulted in design improvements which brought about an economy in construction costs, assessed at $5·25 million. It is also estimated that the reduction of head losses between the Niagara River and the forebay due to these tests represents a capital saving of several million dollars. (J. B. Bryce, *The Engineering Journal*, Canada, Vol. 38, No. 12, December 1955, p. 1663, 8 pp., 17 ff.)

Hells Canyon Projects

Morrison-Knudsen Co. Inc. started construction work immediately after they had been awarded the contract for the Brownlee and Oxbow dams, November 9, 1955. Operations are concentrated at the Brownlee site, first of the three developments planned by Idaho Power Co. for the Hells Canyon area that will ultimately produce over 1 million kW. Access roads and an all-weather camp were promptly completed and, on December 10, portal excavation began for a 2,540 ft. tunnel, 38 ft. in diameter, into which the Snake River is to be diverted next July, to make way for dam foundation work. The Brownlee dam is planned as a rockfill structure 395 ft. in height by 1,320 ft. in crest length; it will require 7·5 million cu. yards of material. The Oxbow development, 12 miles downstream from Brownlee, will make use of a sweeping turn or bow in the river with a 205 ft. high rockfill dam blocking one end of the bow. The power house, at the other end, will receive water diverted across a narrow neck of land, and provision will be made to boost up ultimately by 50 per cent. the initial capacity of 151,000 kW. The third dam, known as Hells Canyon dam and located 23 miles downstream from Oxbow, will be built later to complete the harnessing of the Snake River. (*The Em-Kayan*, Vol. 14, No. 11, Jan. 1956, p. 9, 4 ff.)

Rejuvenating the Face of Old Concrete Dams

Some years ago, at Florence Lake, a multiple-arch structure set up in Southern California at El. 7,300 ft., protection from frost and ice action was achieved by coating one of the arches with a membrane of 12 gauge steel placed against the original dam concrete. A similar method was applied last year to the two high-mountain dams which form Huntington Lake in California's Sierre Nevada, where freezing and thawing conditions are particularly severe. In this instance, 1 in. diameter bolts were first placed in the dam face to hold the 10 gauge steel membrane which was delivered to site in 6 × 20 ft. sheets provided with holes to fit over the bolts. Two such sheets were welded together to permit handling of a single 6 × 40 ft. section during installation, and the double sheets were lowered from the top of the dam by crane. After a horizontal row of steel had been positioned and welded, a new concrete backing was placed, and the new face sealed at top and bottom by an 8 in. channel that is grouted to the dam. Ultimately, the steel membrane was coated with a cold-applied coal-tar enamel material, covered by an aluminium paint to reduce heat absorption. Underlying the new face, a drainage system keeps water out of the existing concrete. The result of pouring concrete behind the thin steel sheets gives the dam face a quilted look. It is not granted that the steel will remain in contact with the new concrete, except when subjected to water load, but the combination of steel membrane, new concrete backing and underdrain system is expected to protect the existing concrete from further severe frost damage. (*Engineering News-Record*, Vol. 156, No. 5, 2.2.1956, pp. 33/34, 2 ff.)

River Control Affects Water Supplies

This short article deals with the problems posed by the Missouri River dams (Garrison, Oahe, Fort Randall and Gavin's Point) for communities using the river for water supply, and the measures already taken or contemplated to adapt the river discharge to increasing requirements. (*Engineering News-Record*, Vol. 156, No. 3, 19.1.1956, pp. 41/42, 1 map.)

John Day Project

In his State of the Union Message, President Eisenhower endorsed for the first time a partnership approach to construction of 1,105,000 kW John Day dam in Oregon which had already been authorised as a federal venture. This, it would appear, reverses last year's decision, when Congress voted $500,000 for Army Engineers' planning, and ignored the offer of three Pacific Northwest utilities to pay the $273 million cost of constructing power facilities on the $310 million project in return for 50-year contracts for the dam's power. The President also endorsed, for the second time, two federal multi-purpose projects: the million kW Upper Colorado River development, and Fryingpan-Arkansas on the Arkansas River in Colorado. (*Electrical World*, Vol. 145, No. 3, Jan. 16, 1956, p. 10.)

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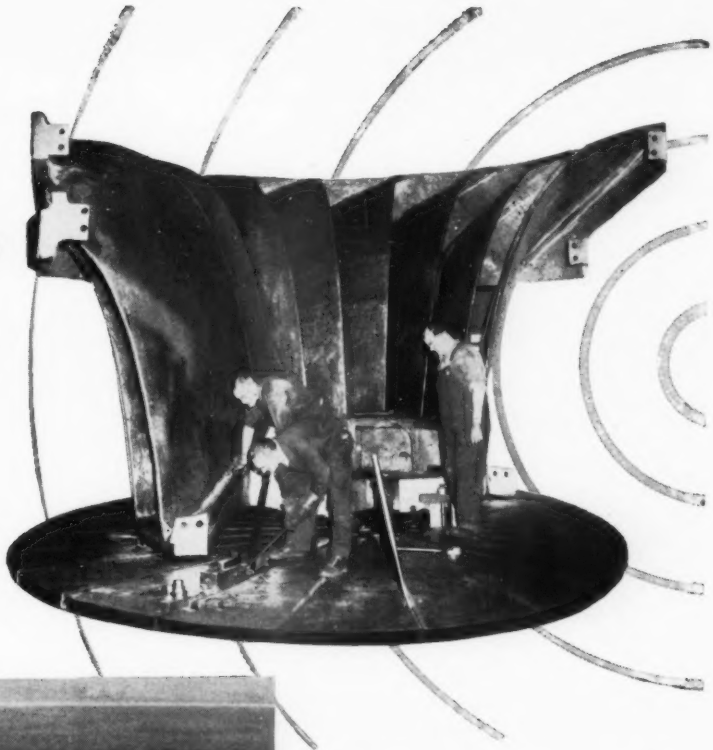

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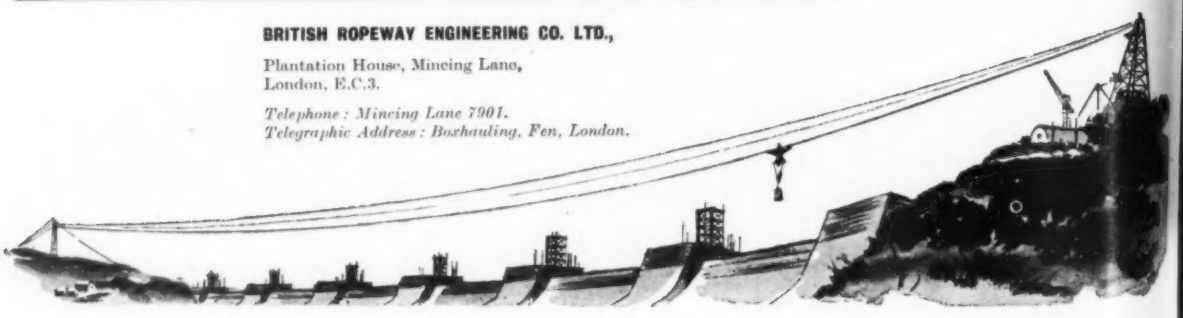

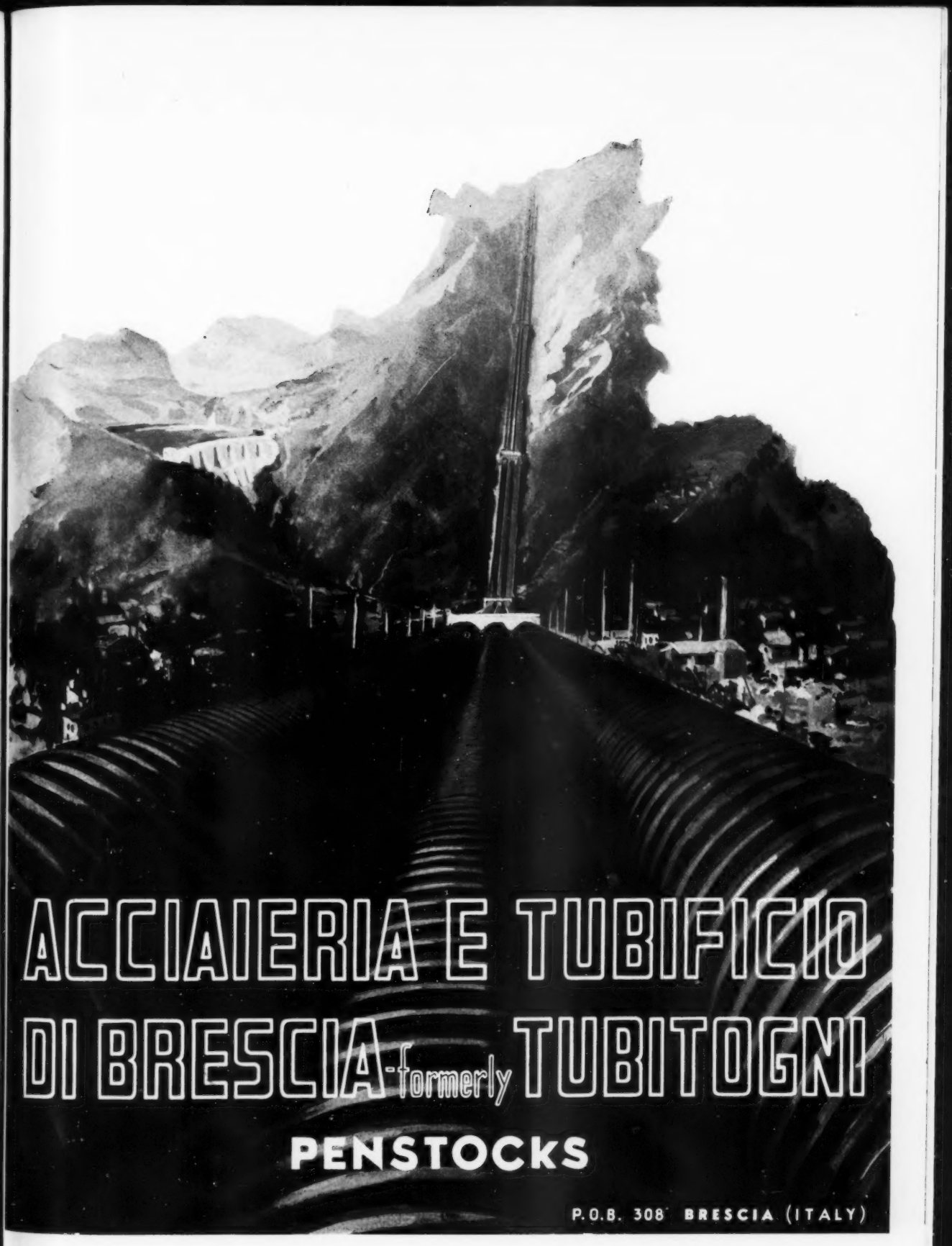
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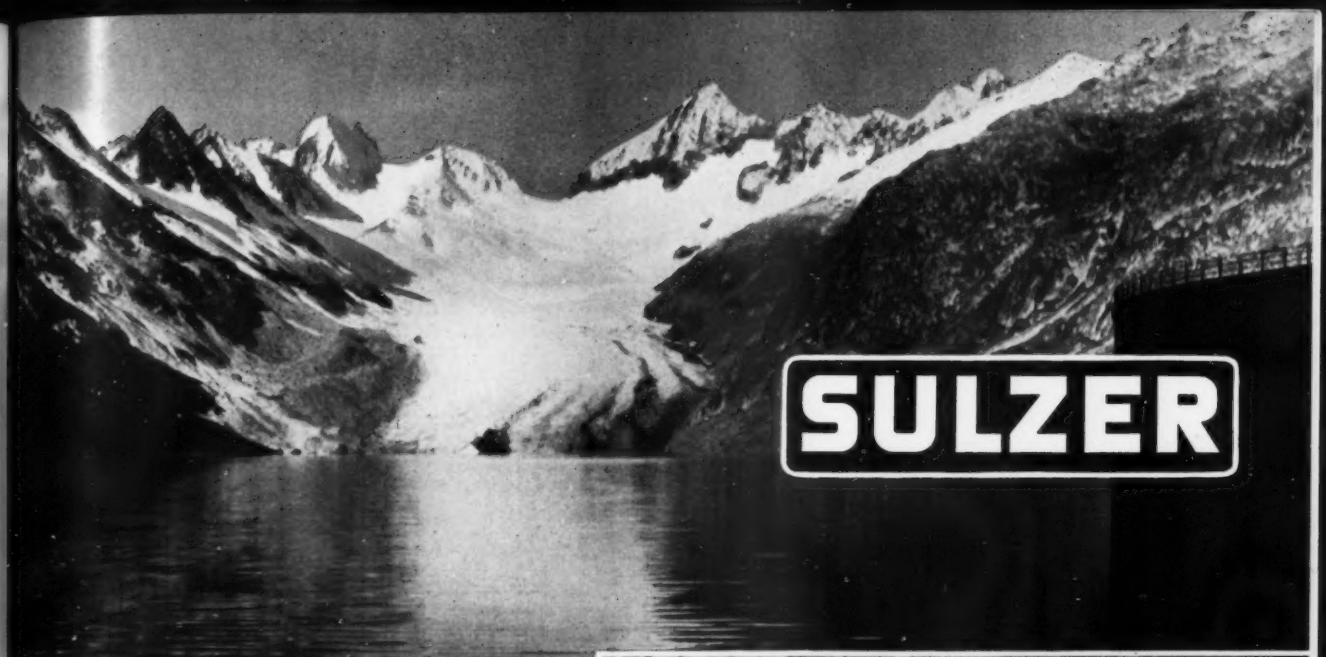

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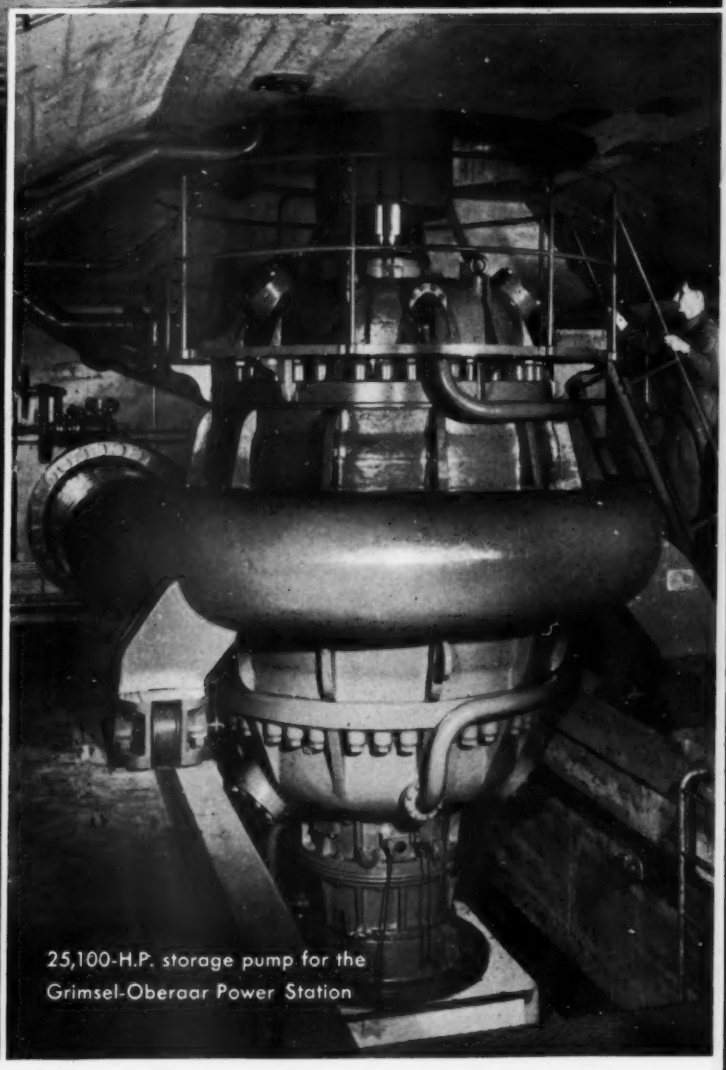

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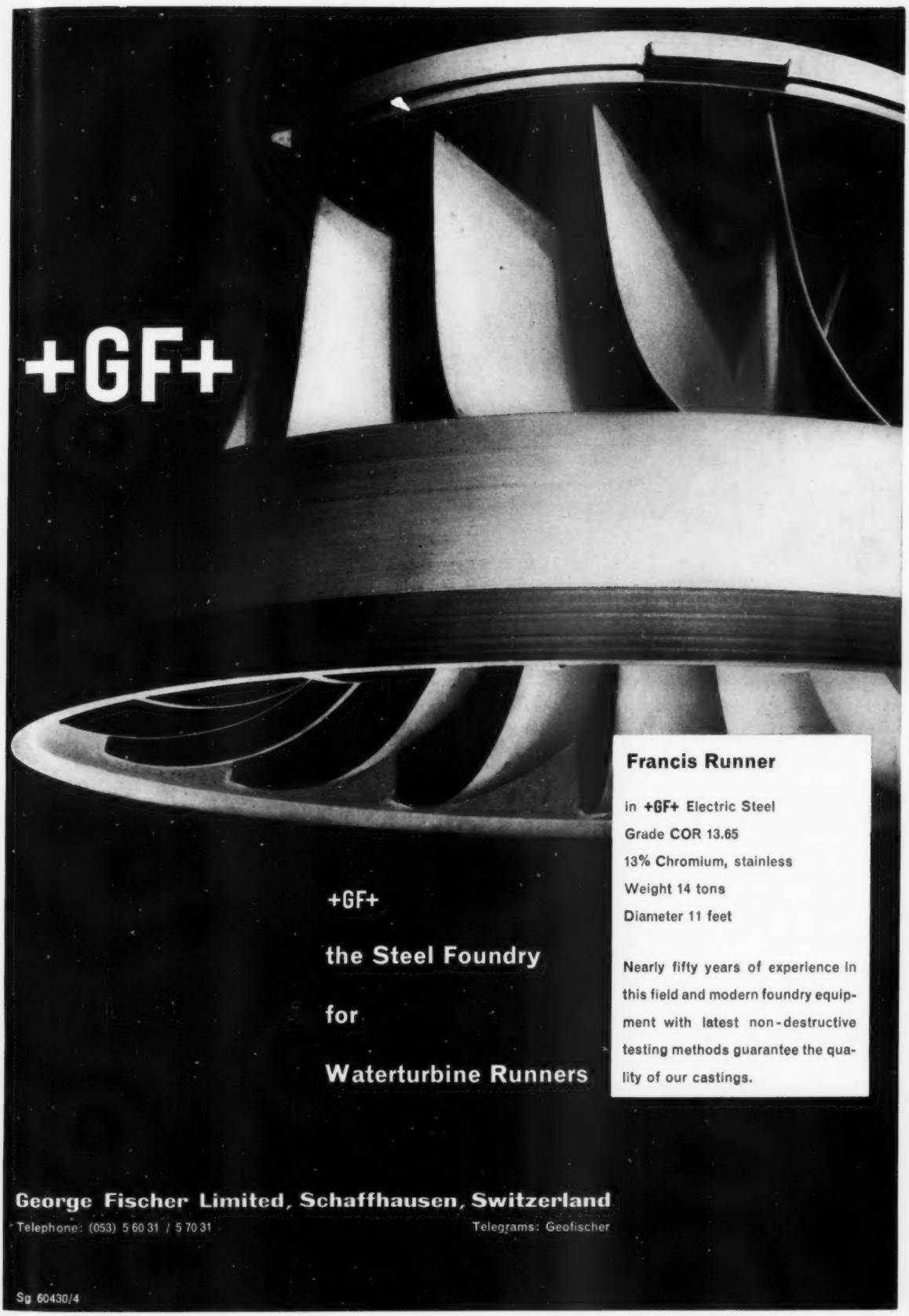
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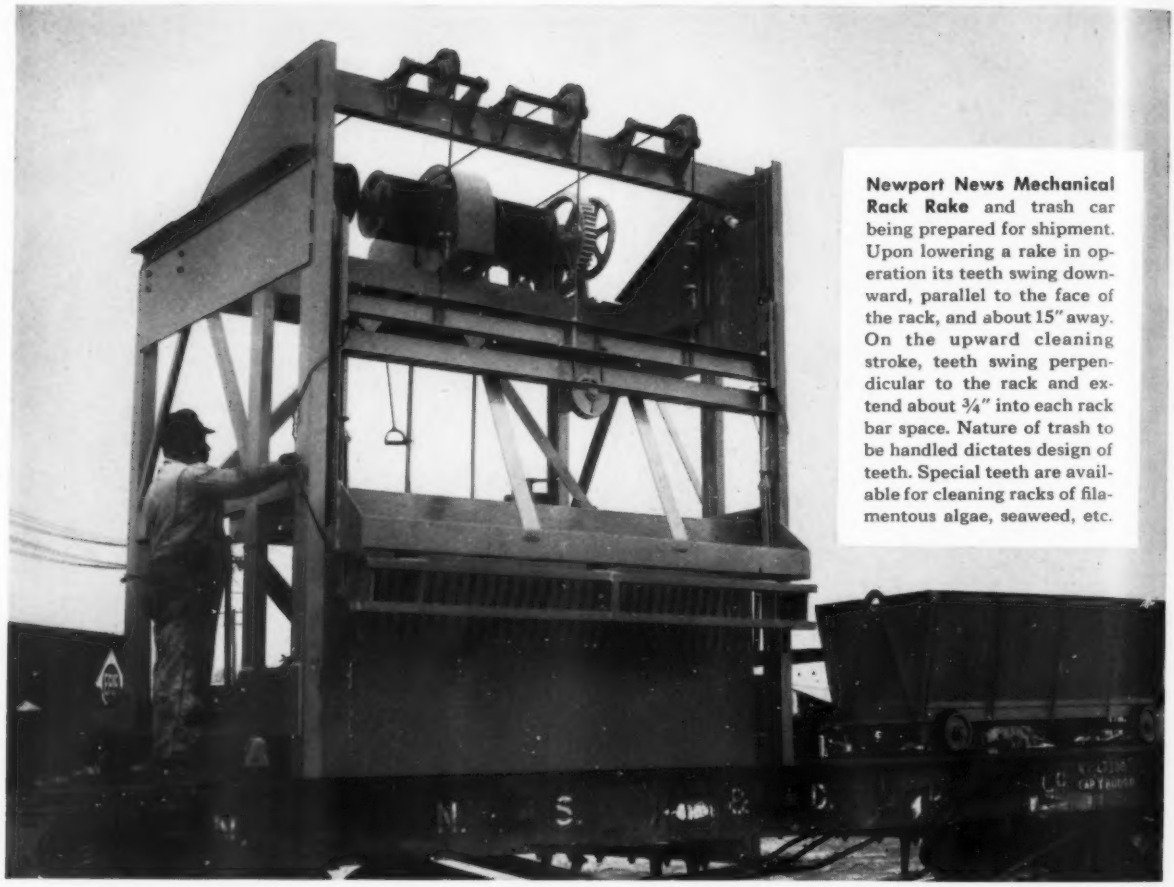

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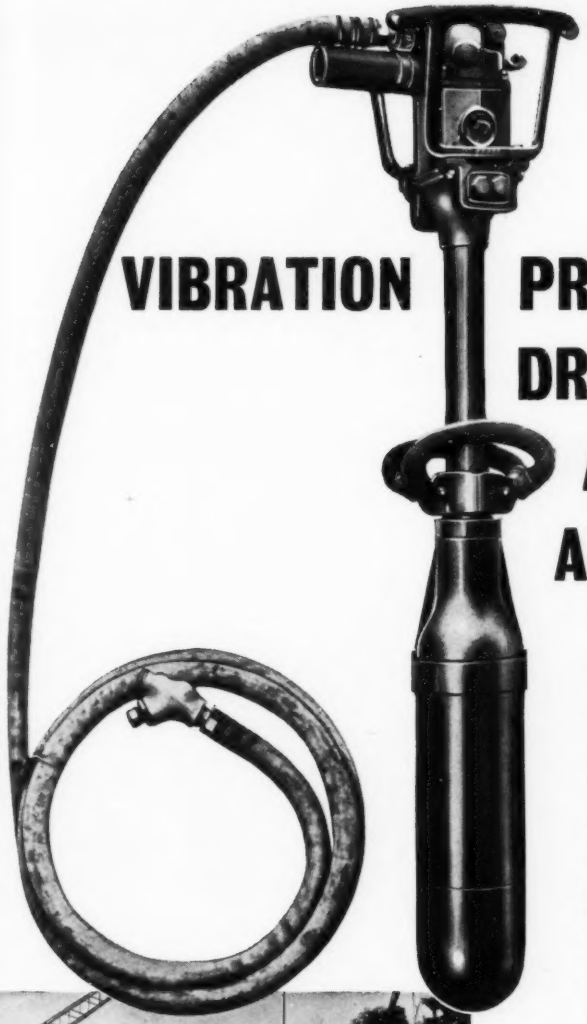

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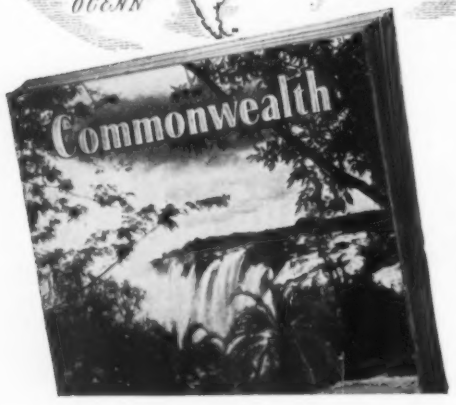

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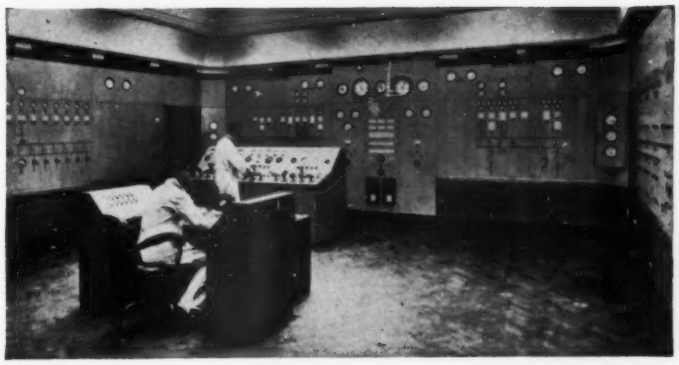

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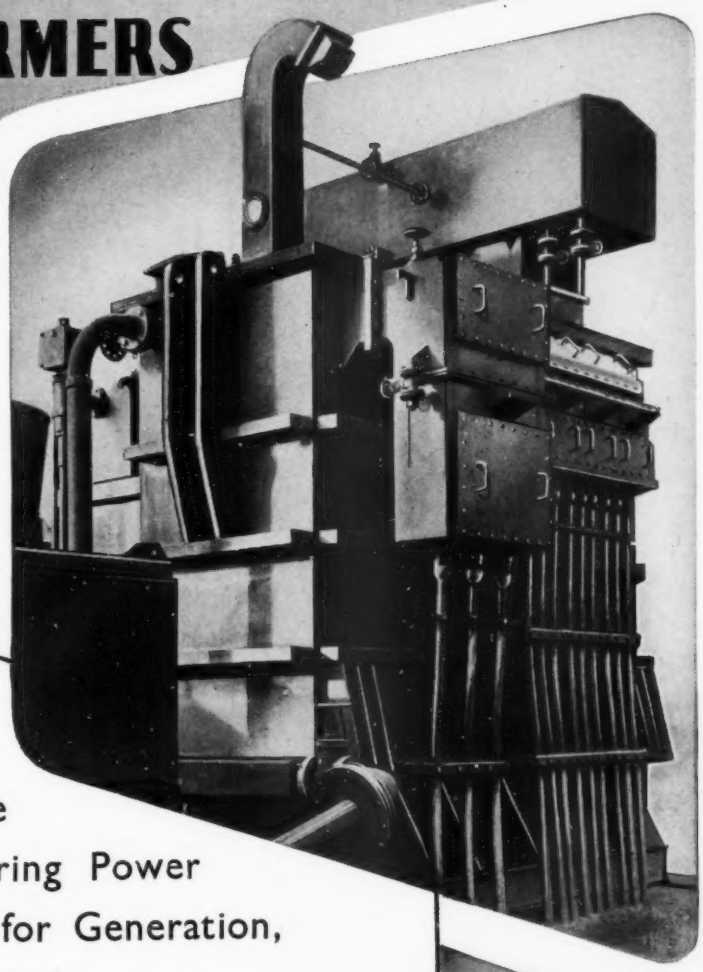

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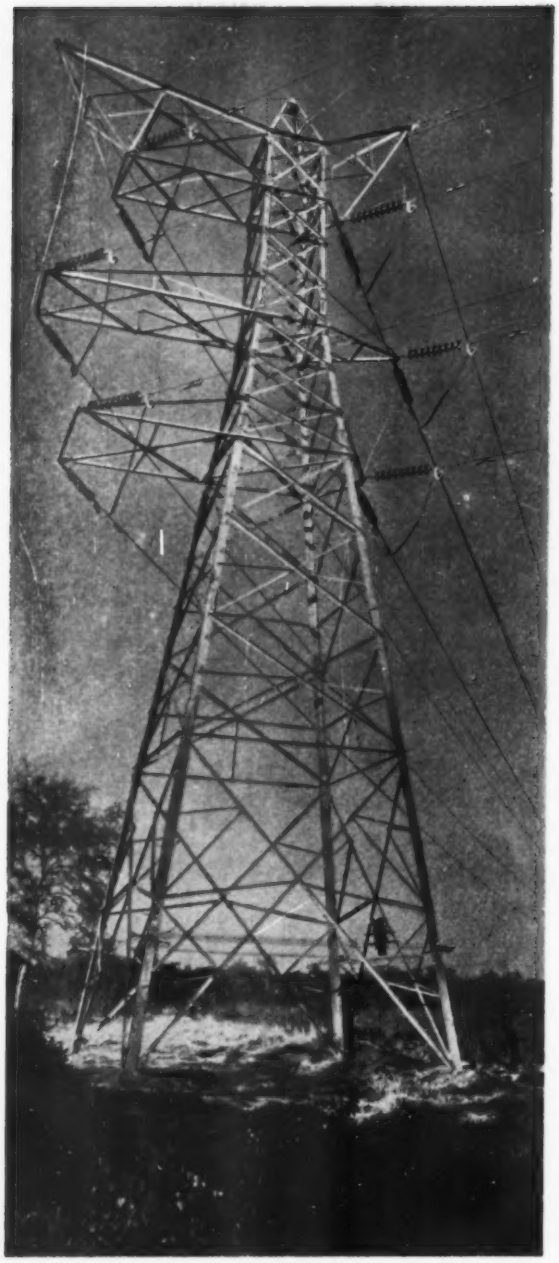

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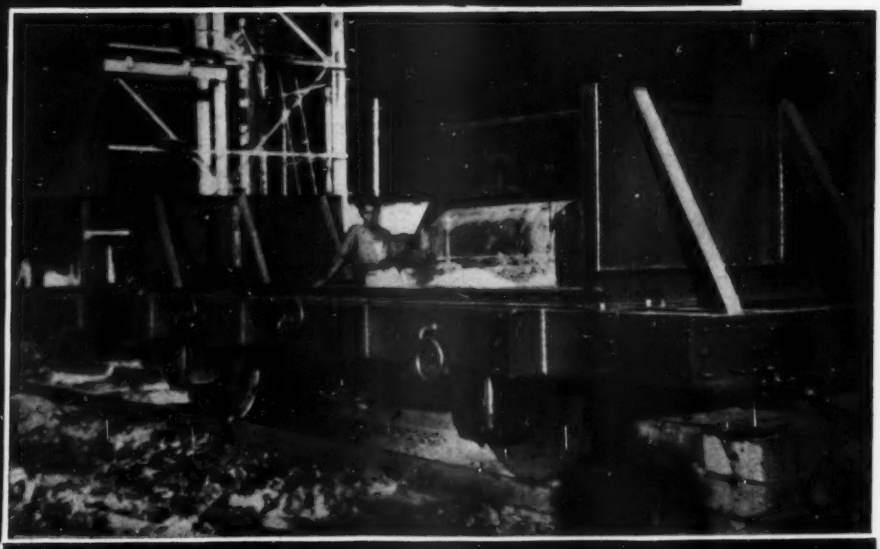

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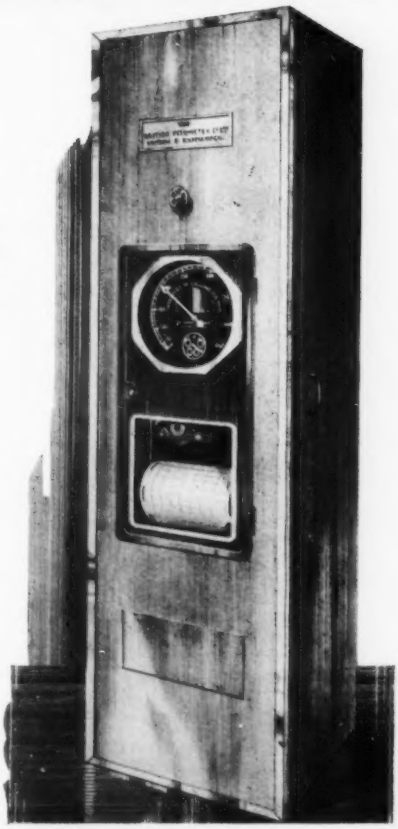

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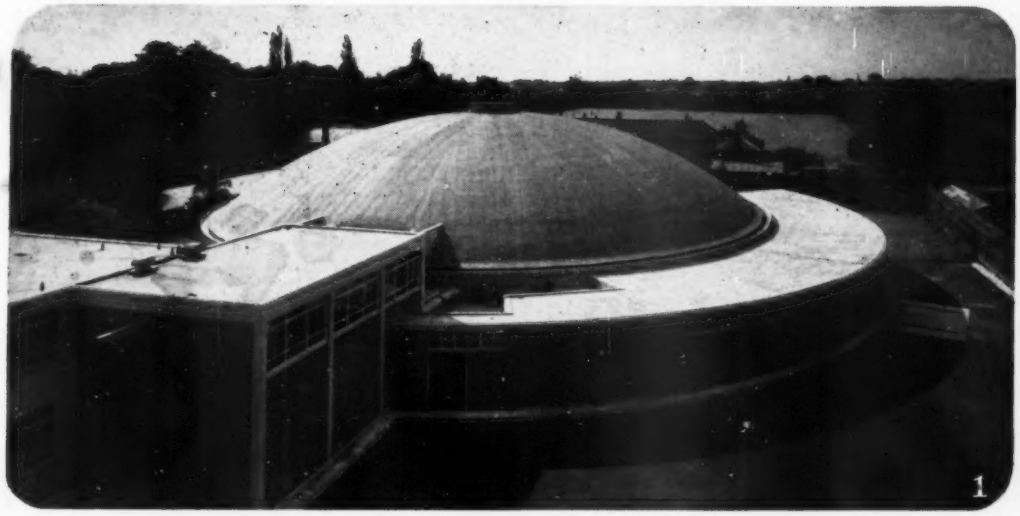
Hydrodynamic Research...



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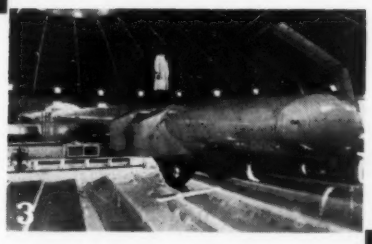

The illustrations show:
(1) The domed structure adjoining the new laboratories.
(2) The annular channel under construction.
(3) Interior view of dome and beam.

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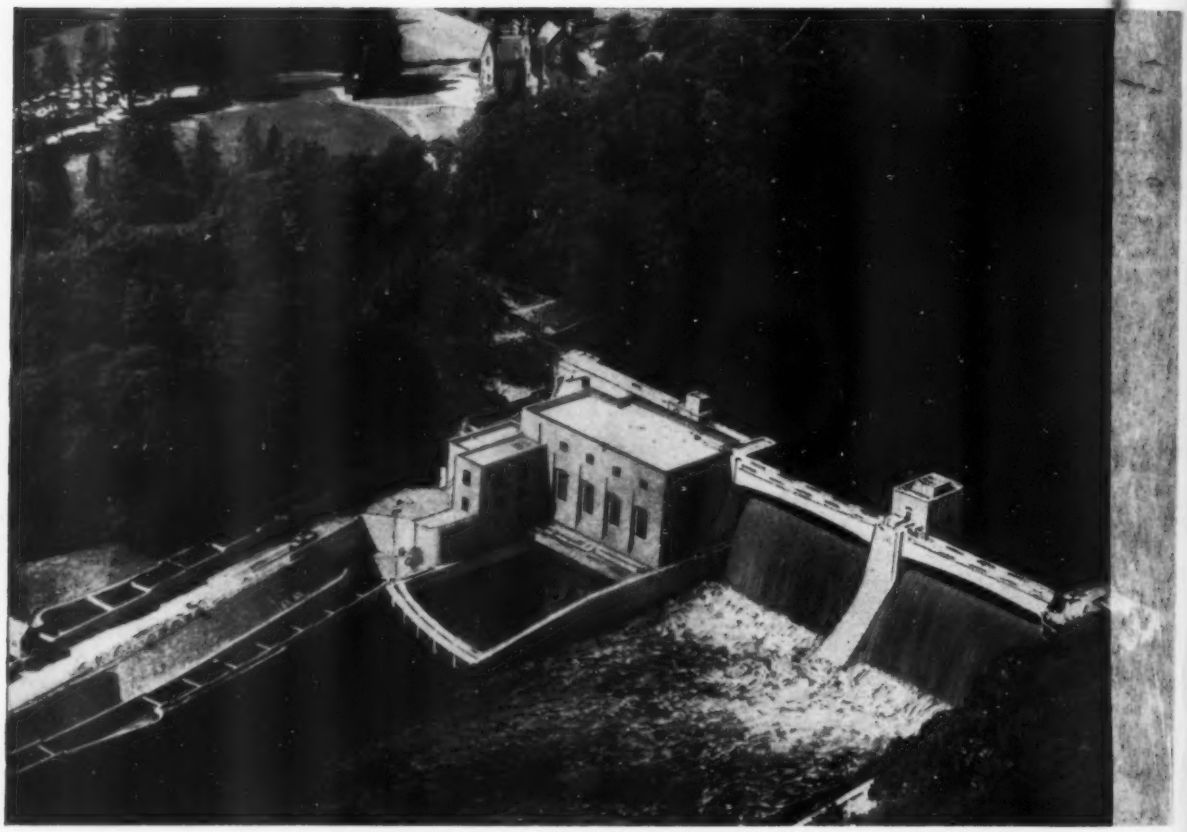

The Pitlochry station of the North of Scotland Hydro-Electric Board, shown in the illustration, contains two 8,333 kVA Metrovick vertical Generators driven by Kaplan turbines of Boving manufacture, operating at a normal speed of 167 r.p.m. and designed for an overspeed of 480 r.p.m. Other Metrovick gear in this station is the generator control equipment including the voltage regulators.

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